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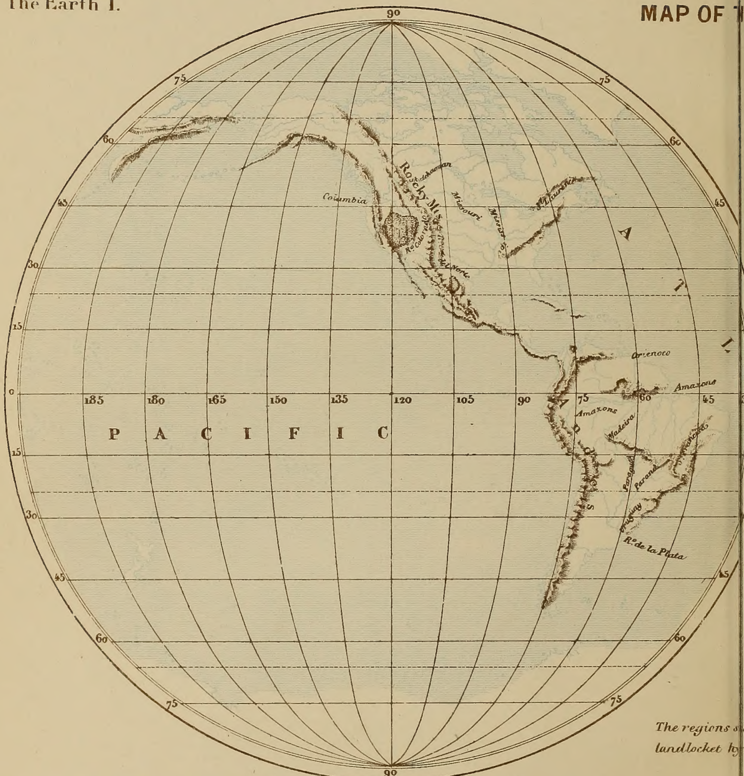

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A NEW
PHYSICAL GEOGRAPHY

BY ÉLISÉE RECLUS

EDITED
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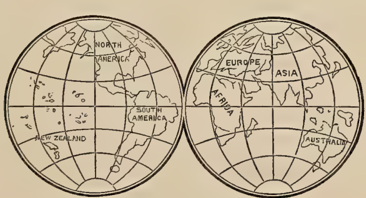
IN TWO VOLUMES

VOL. I.—THE EARTH

A DESCRIPTIVE HISTORY OF THE PHENOMENA OF THE LIFE OF THE GLOBE

Illustrated by numerous Engravings and Maps



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THE EARTH.

PART I.

THE EARTH AS A PLANET.

CHAPTER I.

SMALLNESS OF THE EARTH AS COMPARED WITH THE SUN AND FIXED STARS GRANDEUR OF ITS PHENOMENA.—FORM OF THE TERRESTRIAL GLOBE; ITS DIMENSIONS.

THE earth on which we dwell is one of the lowest in rank among the heavenly bodies. If an astronomer in some other planet were exploring the immensity of space, our earth, owing to its small size, might readily elude his intelligent view. A mere satellite of the sun, the volume of which is 1,255,000 times greater, the earth is but a point as compared with the immense tract of ether traversed by the planets in their courses round their central orb. The sun itself is only a spark, which seems lost amid the eighteen millions of stars which Herschel's telescope discerned in the Milky Way; the latter, an immense agglomeration of suns and planets, which looks to us like a broad streak of light round the whole universe, is in reality nothing but a nebula; that is, a cloud of stars resembling a mist, which would be as nothing in infinite space. Beyond our own sky, other skies stretch far away into infinity, and others beyond these, so that light, notwithstanding its prodigious rapidity, takes eternities to cross them. How small the earth seems in this fathomless abyss of stars! Individually, it may seem immense to us; all too vast for our littleness, we have not yet succeeded in investigating the whole of its surface; but, as compared with the whole sidereal cosmos, it is less than a grain of sand by the side of a mass of mountains, or an atmospheric particle compared with aërial space.

True enough that the earth is nothing but an almost impalpable grain of dust to the vision of the astronomer scanning the nebulæ in the field of his telescope; but it is, nevertheless, quite as much worthy of study as any other of the heavenly bodies. If it does not possess magnitude of dimensions, it presents an infinite variety in all its details. Whole generations, living one after the other upon its

surface, might pass their lives in studying its phenomena without comprehending all their full beauty. There is not even any special science, having for its aim some portion of the terrestrial surface or some particular series of its products, which does not present to our *savants* an inexhaustible field of inquiry. Moreover, is not our little globe, as well as the sky, a real *cosmos*, both by the admirable arrangement of its parts and by its supreme harmony as a whole? In a certain point of view, is not our almost imperceptible planet as great as the universe, in that it is the expression of the same laws? In the form of its orbit, in its movements round the sun and on its own axis, in the succession of days and seasons, and in all the phenomena governed by the great law of attraction, the earth becomes the representative of all the other planets; in studying it, we study all the heavenly bodies.

Our planet is a spheroid; that is, a sphere flattened at the two poles and enlarged at the equator, so that all the circles passing through the extremity of the polar axis form ellipses. The presumed depression of each pole is about thirteen miles, nearly a three-hundredth part of the radius of the earth;* but it is not altogether certain that the two poles are equally flattened. Perhaps a contrast exists between the two hemispheres, not only in the features of their continents and the distribution of seas, but also in their geometrical shape. Be this as it may, it appears to be proved that the curvature is not exactly the same at all points of the earth at an equal distance from the poles; the meridians appear without exception to be irregular ellipses. The recent measurement of degrees carried out by astronomers, and especially the great trigonometrical survey made between 1816 and 1852, under the direction of Struve, from the coasts of the Frozen Ocean to the banks of the Danube, have disclosed some singular deviations in the form of the earth, caused either by the geological nature of the crust or by the vicinity of considerable mountain chains. Thus, among the countries of Europe, the surfaces of England and Italy are sensibly depressed in comparison with adjacent countries.

These inequalities of curvature, which are doubtless variable, and correspond to the changes in the position of the earth's centre of gravity, are cognizable only by the astronomer, and nowhere interrupt the apparent horizontal character of the surface of plains and seas. As far as man is concerned, the roughness and hollows forming our plains, mountains, and valleys are more important than any inequalities in the roundness of the globe. According to Von Schubert, the Academician, an enlargement, perpendicular to the equator, and therefore parallel to the meridian, bulges out all round the globe, passing through Europe and Africa; this hypothesis is not, however, made good by the measurements of an arc of the meridian recently made in India.

The dimensions of the earth, as we have already seen, are almost as nothing compared with the larger celestial bodies, and especially with the extent of space which can be explored by the telescope. If light, the speed of which has been adopted in astronomy as a term of comparison, could be diffused in a curved line, it would travel seven times round the globe in a second of time; this standard of measurement, therefore, the only one suited to the stellar field, is completely inapplicable to the surface of our globe. Man, small as he is in comparison with the planet on which he lives, in the first instance selected for the measurement of his domain, either parts of his own body, such as the *foot*, *cubit*, or *fathom;* or the

* According to Bessel, the astronomer, 299·1528. All possible errors are embraced between 302·301 and 296·005.

distance travelled during a certain period of time, as the *parasang*, *stadium*, *mile*, or *league*. The true measure was found when Aristotle, Eratosthenes, Hipparchus, and other astronomers succeeded in accurately determining a degree of the meridian, and thus, in the language of Strabo, "filling the vast space stretching from the earth to the firmament." Then, according to M. Faye, was discovered the "mile," or sixtieth part of a degree, a unit of measurement afterwards modified through the ignorance of mediæval times.

It was not until the end of the last century that the *savants* who then adorned France conceived the idea of dividing the circumference of the earth into equal parts, which for the future should serve as a standard of measure for all terrestrial distances. This measure, or *meter*, which, with the aid of its multiples and divisions, enables us to estimate with equal ease the circumference of the globe or that of an almost invisible molecule, is the ten-millionth part of the arc described from the equator to one of the poles. Owing to errors which the difficulties of actual measurements rendered inevitable, the ideal *meter* exceeds the customary one by nearly the eleventh part of a *millimeter;* but this very trifling difference, which is imperceptible to the naked eye, may be disregarded in practice without any inconvenience. A line, therefore, going round the earth, and passing through the two poles, would be of the length of about 40 millions of *meters*, or 40,000 *kilometers*. Thus, as Schubert remarks, it is about the distance which the usual pace of a man would travel over in a year—that is, if he did not stop for a single instant. The superficies of the globe, as calculated by Wolfers, according to the most recent measurements which astronomers have made of the arcs of the longitude and latitude in various countries, is 197,124,000 square miles. According to Encke, the astronomer, it amounts to 197,108,580 square miles, and the planetary mass would attain to a bulk of 256,000 millions of cubic miles.

CHAPTER II.

MOTION OF THE PLANET.—DIURNAL ROTATION AND ANNUAL REVOLUTION.—SIDEREAL AND SOLAR DAY.—SUCCESSION OF DAYS AND SEASONS.—DIFFERENCE OF DURATION OF THE SEASONS IN THE TWO HEMISPHERES.—PRECESSION OF THE EQUINOXES.—NUTATION.—PLANETARY PERTURBATIONS.—MOVEMENT OF THE EARTH TOWARDS THE CONSTELLATION HERCULES.

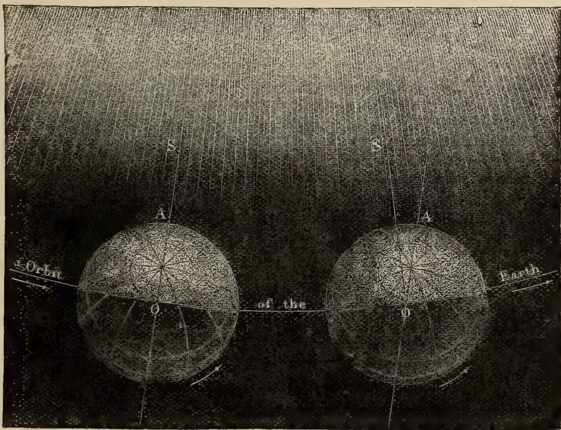
THE isolated globule in the immensity of space, which we call the earth, is not motionless, as the ancients necessarily supposed, looking upon it, as they did, as the immoveable base of the firmament of heaven. Hurried on in the vortex of universal vitality, our globe is ever actuated by ceaseless motion, describing in ether a series of elliptic spirals so complicated that astronomers have not yet been able to calculate their various curves. Besides rotating on its own axis, the earth describes an ellipse round the sun, and, under the influence of this body, is drawn along from one heaven to another towards distant constellations. It also oscillates and rocks on its axis, and deviates more or less from its path, to salute, as it were, every heavenly body which meets it. It is probable that it never passes a second time through the same regions of the air; yet, if it has again to traverse the spiral line of ellipses it has already described, it would be after a cycle of so many thousands of millions of years, that the earth itself, completely transformed, would be no longer the same planet. Nature, immutable in its laws, but for ever variable in its phenomena, never repeats itself.

The motion of the earth, the immediate effects of which are the most obvious to the notice of men, is the daily rotation which takes place round an ideal axis passing through the two poles. The globe turns from right to left, or from west to east—that is, in a contrary direction to the apparent motion of the sun and stars, which seem to rise in the east and set in the west. As the earth's axis terminates at each pole, there is least surface-motion at those points, and the motion is the more rapid in any part of the surface of the globe the farther it is from the central axis. At St. Petersburg, in 60° latitude, the speed of rotation is about nine miles a minute; in Paris it exceeds eleven and a half miles during the same brief time; on the equatorial line, which may be looked upon as the tire of an immense wheel, the speed of the earth is twice as great as it is at 60° of latitude—that is, about eighteen miles a minute, or 528 yards a second—a rapidity equal to the flight of a 26-pound cannon-ball impelled by thirteen pounds of powder. By means of this rotatory motion, the earth presents towards the sun each of its faces alternately, and each also in turn towards the comparatively darker regions of space; the succession of day and night is thus constituted. In addition to this, the rotation

of the earth is an important fact which must always be taken into account in determining the direction of fluids in motion on the surface of the globe, such as streams and rivers, also marine and atmospheric currents.

The annual revolution which the earth performs round the sun follows the line of an ellipse, one of the *foci* of which is occupied by the central star; the eccentricity of the ellipse is nearly equal to $\frac{17}{1000}$ of the great axis. The distance between the sun and the earth always varies according to the particular point of its orbit which the latter is travelling over. At its *aphelion*, that is, its greatest remoteness, this distance is about $93\frac{3}{4}$ millions of miles; at the period of its *perihelion*, when the two heavenly bodies are nearest to each other, it is approximately 90,259,000 miles. The mean distance, as estimated by astronomers since the corrections of Encke, Hansen, Foucault, Puiseux, and Hind, is 91,839,000

Fig. 1.—Inequality of the Solar and Sidereal Day.



miles. This extent of space is traversed by the solar rays in 8 minutes, 14 seconds; sound would take fifteen years in passing through the same distance.

As Kepler has laid down in his celebrated laws, our planet moves with an increased rapidity as it approaches nearer to the sun, and travels more slowly in proportion to its distance from that luminary; but its mean speed may be estimated at nearly nineteen miles a second, or sixty times the rapidity of a ball from the cannon's mouth. This speed, which makes one dizzy to think of, is to be added, as regards each point on the surface of the earth, to the rotatory motion which impels it round the polar axis. Modified by this latter motion, the line described by any one point on the terrestrial superficies becomes a spiral.

After having turned round 366 times on its axis, our planet has terminated its orbicular course, and is in the same position relatively to the sun as at its starting-point; it has then accomplished its *year*. During this period of time, composed of 366 terrestrial rotations, the sun has only illumined each hemisphere in turn 365 times. How does this apparent anomaly arise? How does it happen that a complete movement of rotation performed by the globe round its own axis does not exactly coincide with the solar day? The cause is this—that the earth in its

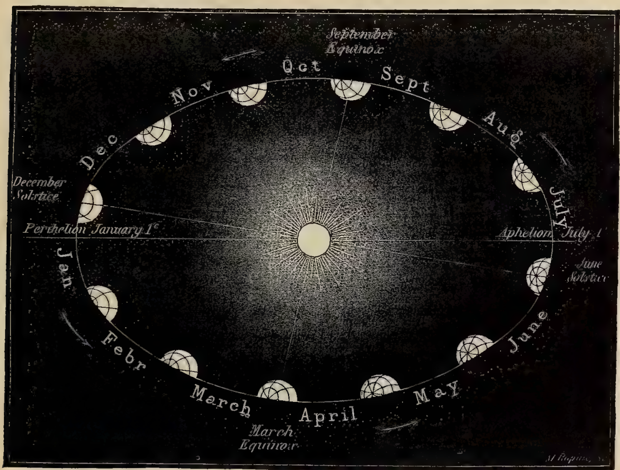
rotation, carried on as it is in its immense orbit, is constantly changing its position in respect to the sun. As regards the fixed stars, situate at an almost infinite distance from our planet, the earth remains, so to speak, always in the same position? Consequently, the sidereal day, that is the interval which separates two transits of the same star over the terrestrial meridian, has the precise duration of one rotation of our globe. After each of its diurnal rotations, our earth presents to these far remote stars the same part of its surface, and if the light of the sun became suddenly extinct, and if a star, such as Sirius or Aldebaran, became our great focus of illumination, our days would have the exact duration of a terrestrial rotation, that is, about 23 hours, 56 minutes. But the sun, although a fixed star, is comparatively near to the earth. Whilst the latter is performing a movement of rotation, it alters its position 1,604,300 miles along the course of its orbit; consequently the sun, in its apparent progress, seems to retrograde this distance, and in order that the earth should present to it exactly the same portion of its surface as at the commencement of its rotation, it would be necessary for it to turn round four minutes more. The next day, a fresh change in the position of the earth again adds four minutes to the duration of the day, and so on till the end of the year. These daily additions of four minutes to the length of the day form during a whole year a period equal to the duration of one of the diurnal rotations; the result is that the sidereal days in the year exceed the solar by one.

Thus the daily rotation of the earth round its axis produces the succession of days and nights, and in the same way its annual revolution round the sun causes the alternations of the seasons. If the axis of the earth—that is, the ideal line which passes through its two poles—were perpendicular to the plane of its annual orbit, it is evident that the portion of the globe lighted by the sun would invariably extend from one pole to the other, and that in both hemispheres the days and nights would always consist of twelve hours each. But this is not the case. The earth performs its revolutionary movements in an inclined position; its ideal polar axis is sloped about 23° 28′ from a perpendicular to its plane, and this position is so far maintained that as regards the comparatively rapid succession of days and seasons it may be looked upon as invariable. This obliquity of axis causes continued changes in the phase presented to the sun. The portion of the earth illumined by the rays of the sun varies every day; for, although the planetary axis may appear to maintain its extremity in a fixed position as regards some point in infinite space, in respect to the sun it presents a constantly varying degree of inclination, in consequence of the continual motion of the earth. Twice during the course of the year it so happens that the solar rays fall perpendicularly upon the equator of the earth; at every other period in the annual revolution, sometimes the northern and sometimes the southern hemisphere receives the greatest amount of light.

The astronomical year commences on the 20th of March, at the exact moment when the sun illumines the equator in a vertical direction, and the line of separation between light and shade passes through the two poles. The period of darkness is then equal to that of light, and admits of exactly twelve hours at all points of the earth. Hence the name of "equinox" (equality of nights). But after this day, which in the northern hemisphere serves as the starting-point of spring, the earth continues its translatory movement. In consequence of the inclination of its axis, the northern hemisphere being turned towards the sun receives a greater quantity of light, whilst the southern half of the globe is less vividly lighted. The vertical rays of the sun now fall more and more to the north of the equator,

and the circle of light, far from arresting its progress at the poles, where the day of six months' duration is commencing to dawn, extends far beyond it over the regions of the north. On the 21st of June, the day of the first solstice, the axis of the earth being deeply inclined towards the sun, this luminary shines on the zenith of the tropic of Cancer, at 23½° north of the equator, and its light illumines the whole of the arctic zone, that is, the portion of the earth's surface extending to 23½° round the north pole. Then spring ceases and summer begins as regards the northern hemisphere. In the southern hemisphere, on the contrary, autumn is giving place to winter. Above the equator long days are prevailing, interrupted by short nights; whilst in the south it is the nights which last the longest. In the arctic zone the sun performs its apparent course of diurnal rotation entirely above the horizon. The six-months' day, which spring inaugurated at the north pole, attains its high noon on the first day of summer. At the same moment midnight arrives in the darkness which is oppressing its antipodes.

Fig. 2.—Orbit of the Earth around the Sun.



Immediately after the 21st of June all the phenomena which took place during the preceding season are directly reversed. The sun appears to retrograde towards the southern horizon; its vertical rays cease to fall on the line of the northern tropic, and constantly approach the equator. The zone of light in the northern pole and of shade in the southern equally diminish, and the days shorten in the northern hemisphere in the same proportion as they lengthen in the southern; an equilibrium is gradually being re-established between the two halves of the earth. On the 22nd of September, the position of the sun is again exactly above the equator, and its light just reaches both poles. The equinox, or the absolute equality of day and night in every part of the globe, occurs for the second time in the year; but this moment of equilibrium is, so to speak, but a mathematical point between the two seasons. The axis of the earth, which during the six months past turned the north pole towards the sun, now presents to him the south pole;

the vertical rays of the central luminary fall to the south of the earth's equator, and the southern hemisphere, in its turn, is the best endowed of the two halves of the globe in the amount of light it receives and in the length of its days. In the southern hemisphere, spring is commencing; in the northern, autumn. Three months afterwards, on the 21st of December, the sun comes directly over the southern tropic, or the tropic of Capricorn, 23½° south of the equator, and the whole of the antarctic zone is presented to the solar rays. Summer has begun in the southern hemisphere, and at the same time winter commences in that of the north. Then, as the globe moves on, these two seasons follow each other in their course, until at length the earth attains a position similar to that from which it started; the March equinox, the first day of spring in Europe, and the first day of autumn in Australia, commences anew the astronomical year.

The elliptical form of the earth's orbit and the unequal pace of the globe in the various points of its course cause some considerable variations in the duration of the seasons. In fact, from the 20th of March to the 22nd of September—that is, during the spring and summer of the northern hemisphere—the earth takes 186 days to travel over the first and largest half of its orbit; whilst during the winter period, from the 22nd of September to the 20th of March, only 179 days are required to accomplish the second half of its journey. The summer period of the northern hemisphere actually exceeds by seven or eight days, or about 187 hours, the corresponding period in the southern half of the globe; added to this, in consequence of the longer space of time during which the arctic pole remains inclined towards the sun in the regions north of the equator, the hours of daylight exceed the hours of night, whilst in the south the hours of darkness predominate. This is, however, to some extent compensated for; as, although in the southern regions of the earth the summer lasts a shorter time, our planet is then closer to the sun; it is at its perihelion, and consequently receives a larger proportion of heat. There is, however, no doubt about the fact, as it is proved by a direct observation both of the winds and currents, and also of their various temperatures, that, taking an equal distance from the equator, the southern regions are colder than those of the north. The problem is, to know if this phenomenon proceeds from the varied distribution of the continents, or from the contrast of seasons presented by the two moieties of the earth. On the whole, does the proximity of the central luminary confer on the southern hemisphere as much additional caloric as the opposite hemisphere gains by its more prolonged exposure to the solar rays? Does it receive complete compensation? Not long ago most astronomers admitted that it did; they maintained this, grounding it on the calculation that in each hemisphere the intensity of the heat is in the inverse ratio to its duration. Other *savants*, on the contrary, the best known of whom was Adhémar, the mathematician, author of an ingenious theory on the periodicity of deluges, assert that, in consequence of the nocturnal radiation, the hemisphere which enjoys the shorter summer must necessarily get much colder than the opposite portion of the earth's surface. We may add, on the authority of James Croll, Lyell, and others, that, in consequence of the eccentricity in the orbit of the earth, the difference of duration between the winter and summer of the two hemispheres may exceed 36 days.

If an equality of seasons between the two halves of the world does not at present exist, it will not fail to be established after a long series of centuries by means of a slow terrestrial movement, which has been known by the name of the *precession of the equinoxes.* Just as a top (if we may be allowed to avail ourselves

of so old an illustration) turns round on the ground and bends over successively in every direction, thus describing with its axis an ideal cone, so the earth revolves in space, and slowly sways the line of its poles. This line, which is always sloped at an angle of 66° 32′ to the plane of the terrestrial orbit, turns round with a slight lateral motion, so as always to point to a new region of the sky; if it were prolonged indefinitely it would describe a circle amidst the distant stars. As the axis of the earth is constantly changing its direction in this way, the plane of the equator must vary exactly to the same extent in its position as regards the sun. In fact, every year the exact moment of the March equinox anticipates by about twenty minutes the time at which the corresponding equinox fell in the year preceding. Each revolution of the earth round the sun brings a fresh advance of twenty minutes in the determination of the equinox; and as, during the long course of ages, the axis of the earth does not intermit in this swaying motion, the time must come, after a period of 12,900 years, that the conditions of the seasons will be altogether changed. The hemisphere which hitherto received the larger proportion of heat will receive the lesser share, and that half of the globe which had endured the larger number of wintry days will now in its turn enjoy the more lengthened period of summer. Then, after a second period of 12,900 years, during which the relation between the seasons of the two hemispheres is being gradually modified, the axis of the earth completes its round of swaying, which has lasted for 258 centuries, and the position of the globe in respect to the sun being nearly the same as at its starting-point, a second cycle of seasons will then commence.

We might call this period *the earth's great year*, if, at the end of it, the earth were in an identical position to that which is occupied at the commencement; but this is not the case. The attraction of the moon, and the disturbances caused by the vicinity of certain planets, are incessantly modifying the curve described in the starry fields of space by the earth's axis, and complicate it with a multitude of spirals, the various periods of which do not coincide with the great period of the swaying of the axis. The successive undulations form a continuous system of interwoven spirals. It is a manifestation of the infinite.

But even this is not all. In addition to all the motions of the globe which we have already pointed out—its diurnal rotation, its annual revolution round the sun, the rhythmical swaying of its axis, proved by the precession of the equinoxes, the nutation or more rapid swaying which is caused by the attraction of the moon—we must now notice the enormous translatory movement which is dragging it through endless tracks of space in the train of the sun. Not many years ago this motion was entirely unknown to astronomers, and yet it is going on with an inconceivable rapidity—a rapidity more than double that of the course of the planet round its central luminary. In one second of time the earth moves about forty-four miles towards the point of the heavens where we find the constellation of Hercules. During one year only she travels 1,382 millions of miles in this direction. Does this enormous distance—which light itself would take two hours and five minutes in traversing—form part of an ellipse described by the whole planetary system round some centre of attraction—a centre which Maedler, the astronomer, has fancied that he has discovered in *Alcyone*, in the midst of the Pleiades? Or is it, as Carus supposes, a portion of an orbit which has for its focus (like the curves of multiple stars) a centre of gravity common to many stars—nothing but a mathematical point everlastingly changing in infinite space? We cannot tell; but certainly this movement of the globe we live on, and its progress

through the unfathomable depths of space, must give us an idea of the immense variety of the motions which make the heavenly bodies gyrate like particles of dust in a whirlwind. Our own little earth itself is carried on from space to space, and never closes the cycle of its revolutions. Ever since the time when its particles were first grouped together it has been describing in space the infinite spiral of its ellipses, and thus will it go on turning and oscillating in ether until the moment when it will exist no longer as an independent planet. For the earth, too, must have an end; like every other body in the universe, it comes into existence, and lives only to die when its turn comes. Already its annual motion of rotation is diminishing in speed. Certainly, this slackening of pace is not very observable, since no astronomer from Hipparchus to Laplace has yet exactly defined it. But unless some cosmical force acting in a contrary direction compensates for the loss of speed caused by the friction of the tides against the bed and the shores of the ocean, the impetus of our planet will every century diminish. After various catastrophes which it is impossible to foresee, the earth will eventually completely change its course of action, and lose its independent existence, either uniting itself with other planetary bodies, or breaking up into fragments; or it will perhaps terminate its course by falling like a mere aerolite upon the surface of the sun.

CHAPTER III.

VARIOUS OPINIONS AS TO THE FORMATION OF THE EARTH.—LAPLACE'S HYPOTHESIS; GRAVE OBJECTIONS RAISED TO IT.—THEORY OF A CENTRAL FIRE; OBJECTIONS TO IT.

THE origin of the earth is lost in the dark night of our ignorance. From the observations and deductions they have made, none of our scientific men have been enabled to afford us any exact information as to the way in which our planet was formed, although new stars are constantly showing themselves in the infinity of space. The telescope serves only to demonstrate the appearance of these celestial bodies, and fails to disclose to us the mode of their formation. On one occasion only, in December, 1845, astronomers had the good fortune to witness the division of a comet—that of Biela; they saw it, in fact, break asunder and form two *nuclei* of unequal sizes, which travelled on into space, one following the other. But this isolated fact will not justify us in assuming a similar mode of formation as regards all the heavenly globes, and in asserting that the stars and planets are produced by a kind of bipartition or duplication. The human intellect is still compelled to be content with mere hypotheses as to the origin of our own and other planetary globes. All cosmogonies, from the legend of the savage who imagined that the earth sprang from a sneezing fit of his god, down to the theory of the great Buffon, according to which the planets of the solar system are the fragments launched into space by a collision between a comet and the sun, the vague conjectures of the ancients, and the ideas struck out by modern science—all alike are mere suppositions more or less plausible and ingenious.

The hypothesis which at the present day still receives the most credence is that which was first proposed by Kant, the philosopher (1755), and having been developed by Herschel, was taken up and largely descanted on by Laplace in his "Exposition du Système du Monde." So great is the authority of this illustrious geometrician, that a great number of persons erroneously look upon his hypothesis as a clearly demonstrated scientific fact. It is, therefore, hardly permissible to omit giving some description of it, even in the briefest sketch of the primitive history of the earth.

Laplace supposes, in the first place, that the space in which the solar system now moves was filled by a gaseous cosmical matter of a high temperature, the dilation of which was excessive, compared even with the most rarefied gases. This enormous nebula incessantly radiated heat around it, and thus supplied a portion of its caloric to the surrounding space; it, therefore, necessarily condensed gradually round a central point, destined one day to become our sun. The particles of

gaseous matter being mutually attracted to one another were not only subject to the motion of condensation, but were also hurried on in an immense circle round the axis of the system. The loss of caloric and the consequent concentration of the spheroidal mass had the effect of increasing the speed of rotation. At the same time the centrifugal force was proportionately increased, and, under the influence of this force, the atmospherical mass, becoming flattened at the two poles, assumed gradually the form of a disc. The attraction which had hitherto retained in their place the molecules of the circumference, and had prevented them from rushing off into space, was at last counterbalanced by the centrifugal force, and although the larger portion of the gaseous mass continued to condense around the central nucleus, the outer zone, acted upon at the same time by two opposite forces, ceased to modify its distance in respect to the axis of the spheroid, and assumed the form of a circular revolving ring.

Other rings were in succession separated from the diminished mass in the same way, and continued to describe their rotatory movement round the nucleus or sun. According to the hypothesis, these rings were the future planets of the solar system. The lightest were necessarily those which were the most remote from the sun, on account of the greater tenuity of the incandescent atmosphere of which they were formed. The heaviest were those which were subsequently constituted out of the denser gaseous layers which were situated nearer to the centre of the sun. It is, we may remark, a matter of fact that the planets farthest removed from the central focus, such as Uranus and Neptune, have the specific gravity of cork, and that the density of the globes increases (although not following any absolutely regular law) as they are in closer propinquity to the sun, until we come to the small and heavy planets in the interior of the system. Besides, the planes of the planetary orbits, which are slightly inclined towards one another, would point out the position of the sun's equator at each of the epochs when one of the great disruptions took place, which gave rise to a fresh planet.

Although constantly getting more compressed, owing to the gradual loss of their caloric, these annular bodies retained their shape through a more or less prolonged series of ages; but, as soon as one of these segments became denser than the rest (in consequence of some astronomical perturbation), it exercised an ever-increasing force of attraction, and at last, breaking up the zone of gaseous matter, gathered the matter round itself in a concentric atmosphere. Under the influence of the laws of rotation, the new planet soon assumed a spheroidal shape, analogous to that of the body from which it had sprung. In consequence of the first impulsive force communicated to its molecules its motion became twofold—it continued its revolution round the sun, and began to turn round on its own axis.

The formation of satellites is similarly explained by the gradual shrinking of the gaseous mass of the elementary planets. The rings separated from the equatorial zone of these bodies would be likewise condensed, and contracting in consequence of the abstraction of their caloric, would become so many moons. The pale rings of Saturn are the only objects in the heavens which would recall the ancient shape of the spheres which the condensation of the sun, and afterwards that of the planets themselves, have thrown off successively into space. Once upon a time, according to the hypothesis, they were nothing but an equatorial enlargement of the mother planet; some day they will become spherical satellites, like the eight moons which now illumine the short nights of Saturn.

Thus, according to Laplace's ideas, the whole planetary system formed, in long past ages, a portion of the sun. This luminary, composed solely of gaseous

particles much lighter than hydrogen, pervaded with its enormous rotundity the whole of the space in which the planets, including Neptune, are now describing their immense orbits. The diameter of the solar spheroid must then have been 6,500 times greater than it now is, and its bulk must have surpassed its present volume by more than 860,000 millions of times. In the same way, the earth, before it began to get cool and solidify, would have embraced the moon within its limits, and its diameter would have been nearly six times greater than that of the planet Jupiter. But, unsubstantial and aërial as it was, our earth had then nothing but a cosmical life which could hardly be called material; it was not until it became more solid and its outer crust was hardened that it actually commenced its real existence.

This is, no doubt, a brilliant hypothesis, and certainly the most beautiful and simple that any astronomer has yet put forth. It accounts better than any other for the uniform translatory motion of the planets in the direction of west to east; it also apparently agrees in a remarkable way with certain facts in the subsequent history of the earth, as disclosed to us by geology; finally, the marvellous rings which surround the planet Saturn seem to proclaim the truth of the theory devised by Laplace. There have been some experiments on a small scale which appeared to reproduce in miniature the magnificent spectacle presented in the primitive ages by the origin of the planets. M. Plateau, a Belgian *savant*, managed to make a globe of oil revolve in a mixture of water and spirits of wine, which was of exactly the same specific gravity as the oil. When the revolution of the little globe was sufficiently rapid, it was noticed to flatten at the poles and to swell at the equator; after a time it threw off rings which suddenly assumed the shape of globules actuated by a rotatory motion of their own, and turning round the central globe. Although these planets in miniature owed their existence solely to the expansion of the drop of oil and not to its shrinking, any one looking at it might well fancy it was an exact representation of the solar system.

But Laplace himself, in putting forth this hypothesis, says that he does so "with diffidence," and no one has a right to be more confident than the great geometrician. In fact, his conjectures do not account for the presence of comets which gravitate round the sun in determinate orbits, although, according to his hypothesis, they are "strangers in the solar system;" they also fail to explain the elliptical form of the planetary orbits, and the inclination of their axes; finally, they appear to be contradicted by the retrograde motion of the satellites of Uranus. Some of the distant *nebulæ*, which were taken by astronomers to be masses of uncondensed cosmical matter, possess the most fantastic forms, which would be very difficult to explain by means of the new hypothesis; some of the *nebulæ*, too, are variable, and the telescope discloses them to us under very different aspects in succession. Finally, the discovery of the spectral analysis—an eternal glory to MM. Kirchhoff and Bunsen—does not show the chemical composition of the sun to be absolutely similar to that of the planets of the solar system, for this luminary does not contain in its outer layers all the simple bodies discovered in the earth. On the other hand, in its spectrum a substance known as helium has been revealed by the presence of a special band, which is seen in none of the terrestrial rays. We must, therefore, confess that Laplace's celebrated and seductive hypothesis is inadequate to account for all the phenomena which have been observed. The human intellect ever thirsts for certainty, and readily allows itself to be led away to look upon mere conjectures as absolute truths; the ability of fearlessly doubting is not the meanest attribute of genuine philosophy. When the investigator is unable to

discover the truth, let him dare to avow his ignorance and rest courageously on the threshold of the unknown world. But whatever relative value may attach to the hypotheses hitherto proposed, the doctrine of the unity of composition of the heavenly bodies still remains probable. As the great geometrician declared, "earth and heaven are made of the same substance."

Another hypothesis connected with Laplace's brilliant astronomical theory must be added, in order to describe the formation of the planetary crust. When the gaseous ring became condensed into a globe, it would not cease to contract, owing to the continued radiation of its caloric. The whole mass, having become liquid through the gradual cooling of its molecules, would be changed into a sea of lava whirling round in space; but this state was only one of transition. After an indefinite term of centuries, the loss of heat was sufficient to cause the formation of a light *scoria* like a thin sheet of ice over the surface of the fiery sea, perhaps just at one of the poles, where nowadays the extreme cold produces icebergs and a frost-bound sea. The first *scoria* was succeeded by a second, and then by others; next they would unite into continents floating on the surface of the lava, and, finally, would cover the whole circumference of the planet with a continuous layer. A thin but solid crust would then have imprisoned within it an immense burning sea.

This crust was frequently broken through by the lava boiling beneath it, and then by means of the solidification of the *scoriæ* was again united; the cooling process would tend also to slowly thicken it. After a lapse of time, which must have been immensely protracted (since the interval during which the temperature of the terrestrial crust would be lowered from 2,000° to 200° has been estimated, at the very least, at three and a half millions of centuries), the pellicle at last became firm, and the eruptions of the liquid mass within ceased to be a general phenomenon, localising themselves at those points where the firm crust was the thinnest. The surrounding atmosphere, replete with vapours and various substances maintained by the extreme heat in a gaseous state, would gradually get rid of its burthen; all kinds of matter, one after the other, would become disengaged from the luminous and burning aërial mass, and precipitate themselves on the solid crust of the planet. When the temperature was lowered sufficiently to enable them to pass from a gaseous to a liquid state, metals and other substances would fall down in a fiery rain on the terrestrial lava. Next, the steam, confined entirely to higher regions of the gaseous mass, would be condensed into an immense layer of clouds, incessantly furrowed by lightning. Drops of water, the commencement of the atmospheric ocean, would begin to fall down towards the ground, but only to volatilise on their way and again ascend. Finally these little drops reached the surface of the terrestrial *scoria*, the temperature of the water much exceeding 100°, owing to the enormous pressure exercised by the heavy air of these ages; and the first pool, the rudiment of a great sea, was collected in some fissure of the lava. This pool was constantly increased by fresh falls of water, and ultimately surrounded nearly the whole of the terrestrial crust with a liquid covering; but, at the same time, it brought with it fresh elements for the constitution of future continents. The numerous substances which the water held in solution formed various combinations with the metals and soils of its bed; the currents and tempests which agitated it destroyed its shores only to form new ones; the sediment deposited at the bottom of the water commenced the series of rocks and strata which follow one another above the primitive crust.

Henceforward the igneous planet was externally clothed with a triple covering,

solid, liquid, and gaseous; it might therefore become the theatre of life. Vegetables and lowly forms of animals were called into existence in the water and on the land which had emerged from it; and, finally, when the temperature of the surface of the globe had become less than 50°, allowing albumen to liquefy and blood to flow in the veins, the fauna and the flora would be developed, the remains of which are found in the earliest fossil strata. The era of chaos was succeeded by that of vital harmony; but in the immense series of ages we are dealing with, the life which appeared on the refrigerated planet was little else than the mouldiness formed in a day.

According to the theory generally propounded, the solid crust was not very completely formed; it is, indeed, much thinner than the layer of air surrounding the globe, for, following the common estimate, which, however, is purely hypothetical, at 22 to 25, or, at most, 50 miles below the surface of the earth, the terrestrial heat would be sufficient to melt granite. Compared to the diameter of the earth, which is about 250 times greater, this crust is nothing more than a thin skin, a just idea of which may be given by a sheet of thin cardboard surrounding a liquid sphere a yard in diameter. In the case of the earth, this liquid is a sea of lava and molten rocks, having, like the ocean above it, its currents, its tides, and perhaps its storms. The geological revolutions of the globe are only the reaction of the subterranean undulations of this hidden hell, and the mountains of porphyry, greenstone, and ophite are but the congealed ripples of a fiery ocean. Those giants on the seashore, Etna, the Peak of Teneriffe, and the Mauna Loa, bear witness by their eruptions and their lava-streams to the tempests which are raging below the earth's solid crust. Such is the hypothesis which, since the time of its author, the celebrated Empedocles, has been most frequently advocated by philosophers.

It is, in fact, very probable that a great part of the rocks which form the outer portion of our planet, especially the most ancient formations, existed in former times in a state of fusion like that of volcanic lava. As most geologists are of opinion, granite and other similar rocks, forming the principal building-blocks in the architecture of continents, existed once in a soft or semi-soft state; but even if this were placed beyond a question, it could not confirm the hypothesis relative to the origin of our planet, the tenuity of its crust, and the existence of a vast central fire.

The flattening of the earth at the two poles and the enlargement at the equator have been alleged as unexceptional evidence that the globe once existed in a state of liquid incandescence; in fact, any liquid sphere turning round on its axis would necessarily assume this shape on account of the unequal speed of certain points of its bulk. But it may also be asked, with Playfair, whether even a solid globe would not equally tend to enlargement at its equator if it unceasingly rotated for an indefinite series of centuries? For no existing matter is altogether inflexible, and under the powerful pressures exercised in our laboratories, certainly very inferior to the influence of planetary forces, all kinds of solid bodies, as iron and steel, become almost as yielding as liquids. Besides, the observations and calculations of astronomers and geometricians have led them to the belief that the flattening of the earth at the two poles is not a constant quantity, and that therefore there are other laws different from those of the motions of rotation and revolution which assist in modifying the form of our planet. Less probably at the northern than at the southern pole, the irregularity of the sphere appears to be subject to periodical changes during the course of ages, and is also complicated with several other inequalities, elevations, or depressions which the oscillations of the pendulum and the measure-

ment of terrestrial arcs disclose to science. One of the gravest subjects of study presented by physical geography is precisely this mutability of the surface of the earth, which at various points of the globe rises or sinks with extreme slowness. Although we are still ignorant of the certain cause of these risings and depressions, there is at least no reason to believe that they are due to the centrifugal force developed by the rotation of the earth.

Neither must it be forgotten that, under the hypothesis admitted by those who assume the existence of a central fire, our planet is to be considered as actually a liquid mass, as the external crust is in comparison but a thin skin. Under these conditions it would be difficult to believe that this great ocean of lava is not, like the watery ocean, agitated by the alternating motion of tides, and that it does not move twice every day the raft, as it were, which is floating on its surface. It is difficult to understand how it is that the earth is not much more depressed at the poles than it now is, and has not been transformed into a real disc. This flattening of the poles is not more considerable than the mere superficial inequalities in the equatorial zone between the summits of the Himalayas and the abysses of the Indian Ocean. M. Liais attributes the slight flattening of the two poles to the erosion which the water and ice in those parts, irresistibly drawn as they are towards the equator, incessantly cause, year after year and century after century, by the enormous quantity of *débris* torn away from the surface of the soil, which they bear with them. Lastly, M. Bischoff, having ascertained from the principal soundings that have been taken that the sea increases in depth from the poles in the direction of the equator, goes so far as to deny the ellipsoidal form as regards the bed of the sea—that is, over the greater portion of the planetary surface.

The principal argument of those who look upon the existence of a central fire as a demonstrated fact is, that in the external strata of the earth, so far as they have been explored by miners, the heat keeps on increasing in proportion to the depth of the excavation. In descending the shaft of a mine we invariably pass through zones of increasing temperature; only the rate of increase varies in different parts of the earth, and according to the strata through which the shaft is sunk. The heat increases more rapidly in schist than in granite, and in metallic veins more even than in schist; in lodes of copper more than in those of tin, and in beds of coal more than in metallic veins. In the artesian well at Neuffen, in Würtemberg, the temperature increases one degree Fahrenheit for every 19 feet. In the mines of Monte Masi, in Tuscany, near the boracic springs, the increase of heat is one degree for every 24 feet. Near Yakutsk, in Siberia, the heat of the earth increases one degree for every 29 feet of depth. Almost everywhere, however, the progression is less rapid; and the mean depth which in this great stratiform thermometer corresponds to a degree of heat is from 45 to 54 feet. In the mines of Saxony, the increase of heat, according to Reich, is one degree for every 76 feet, and according to Lupton one for every 106 feet in the English coal-mines. In the middle of the Modane tunnel, the deepest yet excavated below the surface, the superincumbent rocks being no less than 5,300 feet thick, the temperature of the rock is only 81° Fahr. In other words, the increase of heat from the summit to the tunnel does not exceed one degree in 200 and even 240 feet. But here the natural conditions have evidently been completely changed by the piercing of the mountain. The deepest mine at present being worked is that of Pribram, in Bohemia, which has been sunk to a depth of over 3,300 feet. Yet in the lower strata the heat of the rock, varying from 74° to 76° Fahr., scarcely increases more than the hundredth part of a degree in every 40 inches. In a well at Saint

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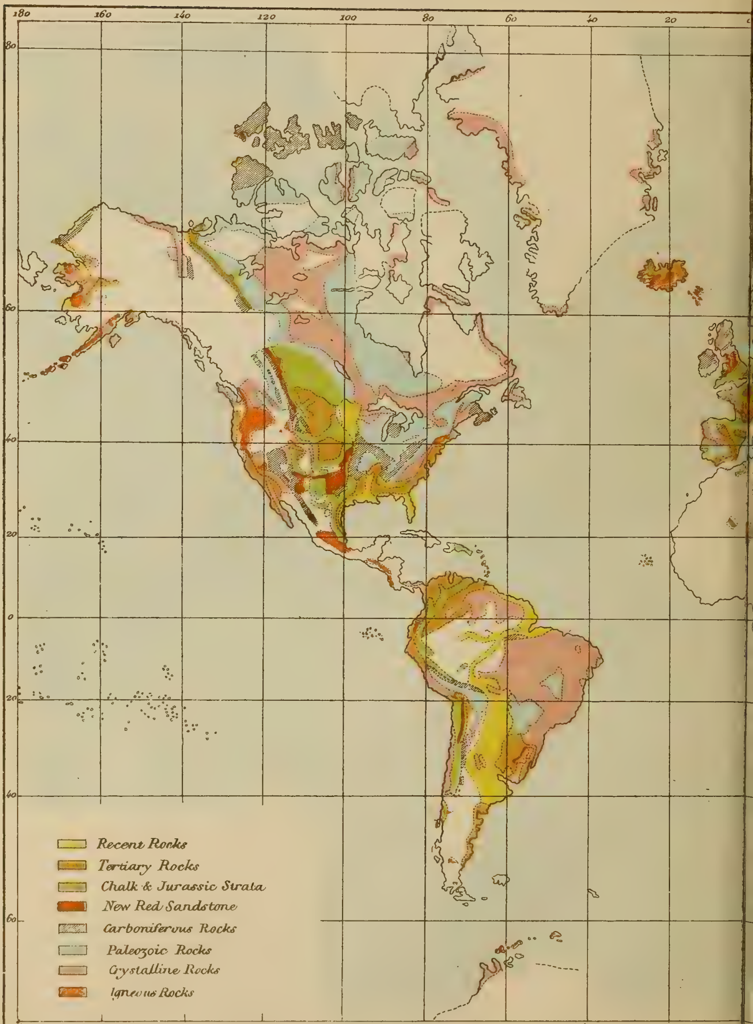

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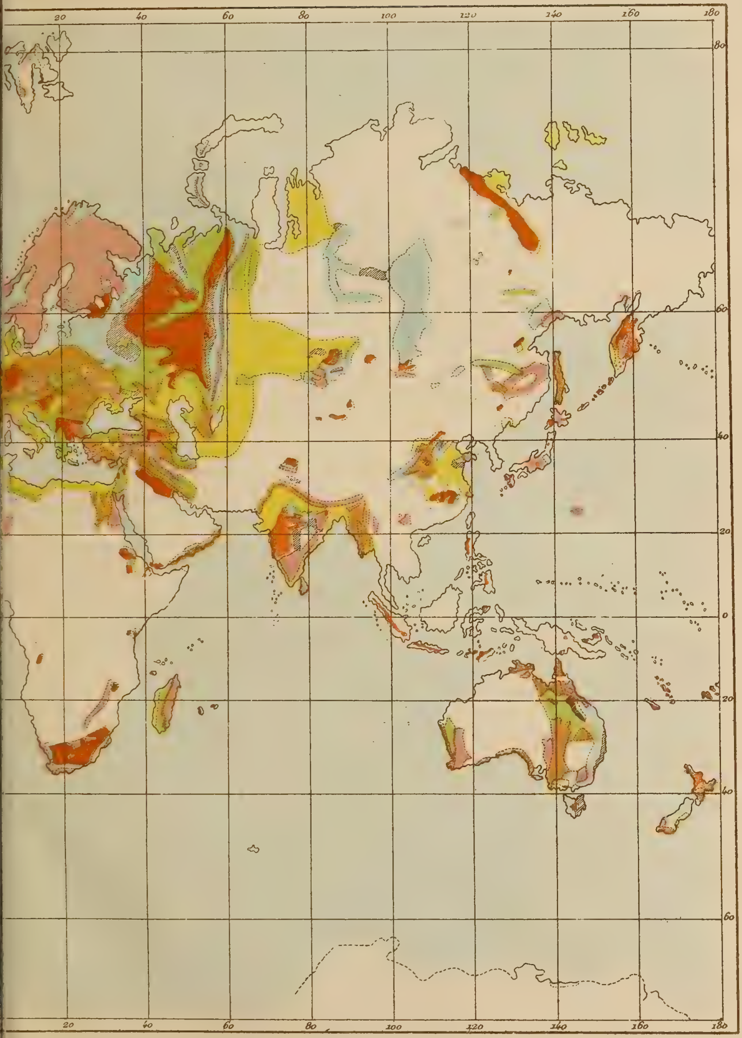

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Louis, on the Mississippi, sunk to a depth of 3,900 feet, the highest temperature is felt at 3,070 feet from the surface. Lower down the heat slightly diminishes, although it should naturally increase by the pressure of the water alone. But it may be doubted whether this experiment has been made under perfectly trustworthy conditions.

Still, the earth has not yet been explored to any very great depth. The most remarkable excavations which have yet been made are those of Kuttenberg, in Bohemia, and one of the mines of Guanajuato, in Mexico; even these have scarcely attained a depth of 1,100 yards, not more than a six or seven thousandth part of the earth's radius. It would, therefore, be something more than imprudence were we to attempt to form a judgment as to the whole interior of the globe by the temperature of the external strata, and to affirm that the heat, increasing according to some constant proportion from the surface of the soil to the centre of the earth, would attain to a temperature of 200,000°—a heat far beyond the power of man's imagination to conceive. In the same way we should have to conclude, from the gradual cooling of the high aërial layers, that the decrease of heat would continue up to the midst of celestial space, and that at 600 miles above the earth the cold is equal to 5,000° below zero. The superficial portion of the globe is traversed incessantly by magnetic currents, taking their course from pole to pole, and in this portion all those phenomena of planetary vitality take place which are constantly modifying the elevation and form of continents; this surface, therefore, must doubtless exist under altogether special conditions as regards the development of heat. It is a noteworthy fact that felspar, which enters so largely into the composition of rocks, presents optical phenomena of quite a different order when subjected to a temperature of over 1,700° Fahr. Hence an intense degree of heat has not been required to produce felspar rocks, such as porphyry and granite, which were formerly supposed to have burst forth like a stream of liquid fire from the vast furnace in the centre of the globe. The thinness of the earth's crust is therefore anything but proved by the gradual increase of temperature in the shafts of mines and other excavations.

M. Cordier, being struck by all the objections which presented themselves to his mind as to the thinness of the terrestrial crust, has admitted that this covering could not be stable without having at least from 75 to 175 miles of thickness.

Mr. Hopkins having subjected to the careful calculations of the higher mathematics all the elements furnished by the phenomena of the terrestrial precession and nutation, has arrived at the following result. He has proved that, either with or without a central fire, our planet would be actuated by periodical movements of a totally different character if the solid portion of its crust had not a thickness of 800 to 1,000 miles; that is to say, about a quarter or a fifth of the earth's radius. MM. Thomson, Emmanuel Liais, and other *savants*, taking up and discussing all these investigations, have endeavoured to prove that, looking at the various astronomical phenomena, the interior solidity of our planet is an incontrovertible fact. M. Roche also thinks that the present shape of the globe and its velocity of rotation may be satisfactorily explained by supposing that the central nucleus, more solid and denser than the outer layers in the proportion of 7 to 3, has assumed its present form under the influence of a rotation less rapid than at present, the contraction due to the cooling of the globe necessarily causing a progressive acceleration of its angular velocity. The terrestrial mass, the centre of which contains the heaviest elements, is analogous in its specific weight to the iron

of aerolites, while the surrounding layer may be compared to meteors of stone. Nevertheless, the recent experiments of M. Delaunay on glass globes filled with water render it very probable that even if the earth contained a mass of molten matter, this mass would rotate, together with the crust, as if it were a solid body, and would adopt a similar course as regards the attractions of the sun and moon. We are not, therefore, warranted as yet in pronouncing any decisive opinion. The hypothesis which seems, both to Mr. Hopkins and also to Sartorius von Waltershausen, the historian of Etna, to harmonise best with the volcanic phenomena, is, that there is no actual central fire, but only internal seas of red-hot molten matter scattered about in various parts of the inside of our planet, situated not far from the surface of the earth, and separated from one another by masses of solid strata.

CHAPTER IV.

GEOLOGICAL STRATA.—CONGLOMERATES.—SANDSTONES.—CLAYS.—LIMESTONES.—FOSSILIFEROUS BEDS.—SEQUENCE OF ORGANIC BEINGS.—GENERAL CLASSIFICATION OF STRATA.—DURATION OF GEOLOGICAL PERIODS.

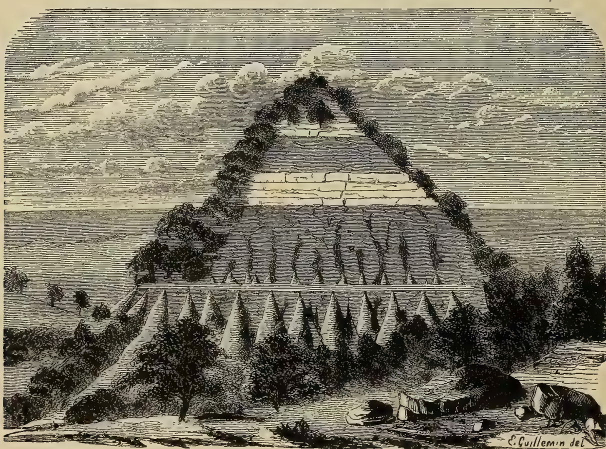
THE outer crust of our planet is mainly composed of oxidised metals—silicium, aluminium, calcium, sodium, potassium, iron, and others, whose mean weight is about two or three times greater than that of water. But the whole mass of the globe, which probably consists largely of iron like an aerolite, is twice as heavy as its outer layer, doubtless, as Grove remarked in his address to the British Association, because in the interior the metals exist in the pure state. It is also to be noted that the particles arriving from the interplanetary spaces in the form of aerolites or meteoric dust, consist chiefly of iron, as shown by the analysis of the substances collected by Nordenskiöld and other observers amid the snows and ices of Finland, Sweden, and Spitzbergen. But these meteorites, possible fragments of distant asteroids, bear a much greater resemblance to our globe than had hitherto been supposed. No simple bodies unknown to us have been found in them, while most of the mineral combinations occur in their crystalline form and chemical nature exactly as on the earth. Whatever apparent differences present themselves are reduced by simple processes to absolute identity.

The most ancient positive evidence relative to the geological history of the earth is afforded by the first sedimentary layers which can be certainly recognised as having been deposited by water on some primitive ocean-bed. Below the superficial strata of more modern origin, we find others belonging to a remoter epoch, and then others of a still antecedent formation; thus we proceed from stratum to stratum, down to the naked skeleton of the earth, or, at all events, to those rocks which the pressure of the masses above and the planetary heat have gradually transformed during the long duration of ages, so as to render their stratification uncertain. These superimposed beds, which have often been compared to the pages of a book, furnish the date of their seniority by the order of their succession; certainly, we cannot say how many hundreds or thousands of centuries have elapsed during the formation of each sedimentary bed, but we may at least learn the relative ages of the series of rocks.

Wherever these strata have not been disturbed since their first origin, they still lie in parallel and almost horizontal layers as at the bottom of the sea which deposited them; in this case nothing is more easy than to class them in their order of seniority. The geologist who descends the shaft of a mine sunk vertically into the earth, may, as it were, traverse the whole series of periods down to the primitive

ages; in a few minutes he may see a kind of abstract of the geological history of the earth. In the same way, in places where the agency of various meteoric phenomena and the forces at work in the interior of the earth have cut through any portion of the upper strata, causing steep escarpments, which show, as on an immense wall, the superimposed beds, the order of succession of the different rocks cannot be the subject of doubt. On the other hand, in countries where the strata have been upheaved at various angles, being either distorted, displaced, or sometimes even completely turned upside down—where rocks springing from the earth in a liquid state, such as porphyry and lava, have forced their way between the beds, the investigations of the geologist become very difficult, and much patience and sagacity are required to attain any result. Finally, the greatest and most difficult problem is to establish the harmony in age and formation between various rocks separated by valleys, large plains, or even by the ocean. Thus, doubt still exists as to a great number of details, and variance on these points often arises

Fig. 3.—The Pyramid Mountain.



among geologists. Nevertheless, whether deciphered or not, these strata, with the various indications which are presented by their minerals and fossils, are the only authentic annals of our planet. They are the hieroglyphics, still in part mysterious, which relate to us in their magnificent characters the history of the world itself.

These innumerable strata, so diverse in their position, inclination, and thickness, are analogous to the beds of the same nature that we notice incessantly in the course of formation. Mountains furrowed out by torrents and cliffs, sapped by the waves, supply either to rivers or direct to the sea masses of *débris*, which, spread out into shingle-strands or beds of pebbles, are gradually changed into solid conglomerates. The crystalline rocks, pulverized by atmospheric agencies and the friction of river and sea water, become submarine sandbanks, which sooner or later are converted, under the pressure of the superincumbent masses, into rocks of sandstone. The tranquil waters of slow-flowing streams and rivers, which neither carry pebbles along with them in their course nor are charged with sandy

matter, are still loaded with small particles of ooze and earth, which they deposit on their banks and in the bed of the sea, forming those beds of clay which also ultimately constitute important geological formations. On the banks of the Mississippi there are enormous argillaceous beds which the water of the river has left behind it; these are apparently no less firm than the rocks which have for centuries met the assaults of the waves and storms. In certain lakes in Mexico, and especially round the reefs of Florida, oolites like those of the Jura are daily being formed before our eyes. Finally, in the shallows of the sea, fresh beds are being formed, as of limestone at Guadeloupe, or of drift brought by the sea as upon the great bank of Newfoundland. In the same way, coral-insects, madrepores, and other marine animals, are incessantly at work in building up new beds similar to those of the ancient geological periods. The formations caused in days of yore by the movement of the water and the perpetual activity of teeming marine life—all are still in progress, and disclose to us in what way the earth's surface was modified during a long series of ages.

Although all strata may be classed in a general way in one of the five great series—conglomerates, sandstone, clays, gravels, and limestone—nevertheless in their various shades of distinction, their relative positions, and the minerals which they contain, they present indications which allow of their being classed according to their respective ages. But the organic remains, animal or vegetable, which are contained in the greater part of these various formations are the means which afford us the principal data for ascertaining, often with certainty, the order of succession of the various layers. Natural history alone enables us to decipher clearly these pages in the earth's history.

That organic remains are preserved in the ground, in an altogether exceptional way, is a fact which naturalists have innumerable opportunities of satisfying themselves of, in the study of the plants and animals of our own time. Dead animals are soon devoured by beasts of prey and insects; water, wind, and sun ere long dissolve all that remains of flesh or ligaments; the skeleton itself is finally reduced to dust. The infinite legions of inferior creatures which have no solid bones disappear in myriads without leaving the slightest trace behind them, and the piled-up masses of their remains are soon changed into *humus* and gas. Forest trees and herbaceous plants disappear like animals, and furnish nutriment to other existences. Scarcely have they perished ere the former organisms aid in forming new ones—death is the constant food of life. The remains of extinct vitality can be preserved for future ages only by being suddenly removed from the tooth of the animal and the action of the elements. Thus organic remains which are clothed by petrifying springs with a covering of lime, and the trunks of trees which are surrounded by sheets of lava, become as indestructible as stone itself. Animals caught in the ice, overwhelmed by falling earth, or which have died in some deep and inaccessible cave, may be kept for centuries in a condition of perfect preservation, and may pass into a fossil state. But although it is comparatively very rare that a terrestrial being is preserved for future ages, either whole or only in fragments, the case is not the same as regards marine creatures, which are engulfed immediately after death, or even during their life, in the sand or mud which is brought by the waves. Thus in the sediments of former marine beds and deltas we find multitudes of fossil animals of which even the most delicate parts are wonderfully preserved. We see this in the beautiful specimens in our museums brought from the beds of Solenhofen, Monte Bolca, Grignon, and Montmartre.

Besides all this, on those shores where the tides are considerable —in the Severn, St. Michael, and the Bay of Fundy—the ooze brought by the waves has frequently covered the footmarks of vertebrate animals, the tracks traced out by crustaceæ, worms, and molluscs, and also the marks made by the rain-drops and by strong squalls of wind. This mud, gradually hardening, may at last become beds of schist, sandstone, and clay; and thus, after millions of years, similar imprints of an instant are found graven on the rocks, deeper and more legible to the eye of the geologist than the ambitious inscriptions of the kings of the world. But these magnificent evidences of the past are common only as regards marine beings; there is very little chance of fossilization for anything which lives on the emerged strata, in the air, or in fresh water.

As the preservation of organic forms, or of impressions made by them, depends on exceptional conditions, a great number of strata are partly destitute of fossils, whilst immediately above and below them geologists are able to discover multitudes of the remains of the ancient inhabitants of the globe. Thus the deficiency of evidence in a stratum absolutely decides nothing against the existence of life in any particular period of the planetary history. The negative conclusions as to life which many *savants* have desired to deduce from the absence of fossils in certain beds are not based on any sure ground. Besides, the exploration of the globe is scarcely commenced, and a number of beds in which no relics had previously been discovered have since presented to science plenty of geological treasures; in addition to which, we must not forget that there are great unexplored tracts at the bottom of the sea, as well as on the mainland.

The appearance and disappearance of fossil species are not in perfect harmony with the succession of rocks, and consequently the idea is not warranted which connects some kind of cataclysm with the end of each geological period. A continuity of life has linked together all the formations, from the first organized beings which made their appearance on the earth down to the countless multitudes which now inhabit it. One species would perhaps live but for a very short period of the planetary history; another species would make its appearance in a certain bed; at first it would be rare, and as if trying to force its way into life; then it would multiply from stratum to stratum, and afterwards would either gradually become extinct, getting less and less through a whole series of ages, or suddenly disappear. Other generic forms appear to have passed through every epoch, and their representatives exist after millions of centuries. The duration of a species does not depend either on the various revolutions which have modified the bed, or on any other external cause, but on its own special vitality. In a general way, the duration of the existence of any series of beings is in proportion to the more or less rudimentary character of its organization. The inferior vertebrate creatures have all pervaded a more extended geological cycle than that in which superior vertebrate animals are found; Foraminifera have run through a much longer series of ages than molluscs; the latter, as well as fishes and reptiles, have a much longer existence as species than Mammalia. Finally, the great mammals of the Tertiary epoch enjoyed but a comparatively short term of existence; they were unable to resist the variable influences of climate so well as the inferior animals. The higher an organism is raised in the scale of being, the narrower are the limits between which it is confined; all that it gains in rank, it loses, if not in number, at least in duration of existence as a species.

In what order did the various species of animated beings follow one another on the earth? Not long ago, geologists put forward a very simple system on this

point. According to their preconceived ideas, the inferior animals, including the class of Crustaceæ, were the exclusive inhabitants of the surface of the planet during the formation of the most ancient geological beds. Fishes made their first appearance during the period of the Old Red Sandstone; reptiles came into existence in those hollows and marshy shallows where the vegetable remains were accumulating which, subsequently, became transformed into coal. Birds, properly so called, first took flight at the Cretaceous epoch; next came quadrupeds in regular order, from the inferior species to the very highest. The ape did not form one of their number until immediately before the appearance of man, and the latter was created after all the other animals, as if to sum up in his person all the long catalogue of anterior life.

The discoveries made during the last few years by indefatigable investigators, such as Lyell, Forbes, Barrande, Owen, Leidy, Emmons, and Wagner, have singularly disturbed the serial order of species which had been previously established. Ferns, *Lycopodiaceæ*, and *Calamiteæ*, which were thought to be the only families represented in the Coal Measures, have been added to by many other species, belonging to other families, and even to the Dicotyledonous order. More, than thirty species of reptiles have been discovered in those very strata in which. according to the views of many geologists, not one ought to have been found Mammals of the marsupial order have been discovered in the Rhætic beds of Somerset, and even in the Trias, at the termination of rocks of Palæozoic formation. Apes, at least as highly organized as those of our day, lived during the period of the Upper Miocene, and man was the contemporary of the cave-bear, of the mammoth, the woolly rhinoceros, and other great animals now extinct. No year passes in which geologists fail to discover in the terrestrial strata new animal and vegetable forms, which transfer our geological horizon to periods still more and more remote. The facts which prove the existence of organisms of a superior class in the more ancient terrestrial beds have become so numerous that certain palæontologists have ventured to doubt the progressive development of the animal and vegetable series during the various geological periods. In their view, it is in each group of species, and not among animated beings as a body, that we must seek for the order of development. If, however, we embrace in one glance the whole body of beings, instead of considering only the earliest and the latest ones, we are bound to recognise that there has certainly been a progress in the organic series. In its period of greatest exuberance vegetable life preceded animal life; in the primitive ages plants destitute of flowers were much more numerous than the flowering species; crustaceæ, molluscs, and other lower animals had their golden age before fishes and reptiles, and the latter appear to have been the lords of the earth before mammals appeared on the scene. Even among the latter it seems very probable that progress was the rule, for most of the animals in the Oolitic beds are marsupials, and it was not until the Tertiary age that the larger mammals attained their more complete development. Agassiz thinks that the types of the ancient epochs represent the embryos of now existing beings, so that palæontology teaches us of the infancy of all those forms of existence which are now found in a fully developed state.

Be this as it may, the fossiliferous geological beds, from the most ancient to the most recent, are all linked one to another by species common to two or more of their number. Thanks to the succession of their different species, and in spite of the numerous variations in the names used by them, geologists are now pretty well agreed as to the general classification of the rocks over the whole surface of the

earth. The most ancient formations, or the Palæozoic, resting on the granite or other rocks of a similar nature, and comprising the Taconic, the Cambrian, the Silurian, and the Old Red Sandstone groups, are the earliest strata in which we find any remains of organic beings; in them, "in the dawn of vitality," sprang into life *Eozoon Canadense* (if, indeed, it exists at all, except in the imagination of certain geologists) and the Braintree trilobite (*Paradoxides Harlani*), which disputes with the Eozoon the honour of having been the "Adam" of the terrestrial Fauna. The *Prototaxides Logani,* the first known plant, has also been found in the sub-Devonian formations of the Erie district. But its character is difficult to determine, being pronounced a conifer by Dawson, an alga by Carruthers. This period of the earth's history, itself the successor of periods all unknown, was followed by the age of Carboniferous beds, including the Mountain Limestone rocks and the various layers of the Coal formations. Above lie the beds of the New Red Sandstone. Next in the geological series come the numerous Jurassic and Cre-

Fig. 4.—Paradoxides Harlani.

taceous stages, known as a whole under the name of *Secondary* rocks. The last period preceding the present epoch witnessed the deposit of the Eocene, Miocene, and Pliocene rocks, and is connected by the Quaternary strata to the formations which are now being constituted before our eyes. Finally, the incandescent lavas, trachytes, dolerites, and basalts, which have made their way from below and have traversed the stratigraphical series, constitute a sixth class of rocks.

Although the general groups are the same in the two hemispheres, the numerous geological strata in the various countries of the world differ singularly in their fossils and other characteristics. Nowhere do they present absolute harmony; and it is therefore very difficult to class them certainly in their respective order of succession. In former times, as now, animals and plants differed according to climates, and therefore the strata which received all these *débris* received each of them its own special geological character. In the varieties which the fossil Fauna and Flora present to us, how much is owing to a difference of epoch and how much to a diversity of climate? The solution of this problem is one of the great tasks of science.

GEOLOGICAL MAP OF ENGLAND.

1/4,485000

Kilometres

10 20 30 40 50 100

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CHAPTER V.

INCESSANT MODIFICATION IN THE SHAPE OF CONTINENTS.—ATTEMPTS MADE TO LEARN THE FORMER DISTRIBUTION OF SOILS AND CLIMATES.—OBJECT OF GEOLOGY.—PROVINCE OF PHYSICAL GEOGRAPHY.

WITH regard to the ages necessary for the accomplishment of the immense geological processes, the history of which is disclosed to us in the earth's strata, they certainly must have been of prodigious duration; for all the annals of humanity are but as a passing moment compared with the cycles of the globe; the cosmogonical chronology of the Hindus can alone give an idea of the periods of the earth's history. All the calculations which astronomers have made as to the duration of the great planetary evolutions result in very formidable series of years, and it is in millions or thousands of millions of centuries that estimations are made as to the duration of these ages. Professor Haughton, a mathematician, has endeavoured to establish, according to the formula of Dulong and Petit, that the mere fall in the temperature of 25°, occurring previously to the present epoch of our planet, would require about 18 millions of years. In the same way, the formation of each of the strata which constitute the sum-total of the geological records of the earth's surface must have taken up a long series of centuries before which the mind recoils in perplexity.

The unceasing transformations of all the rocks which compose the outer layers of the globe could not have taken place without at the same time modifying the elevation and outline of the land; thus the general configuration of the emerged portions of the surface has never ceased to vary since the first ages of the globe. The old mountain chains have crumbled down, stone by stone, and particle by particle, and have been distributed, in the form of sand and clay, over plains and seas; on the other hand, ocean-beds have gradually been elevated, and have changed into dry land, which has here and there been upraised into hills and ranges of peaks. Strata, when scarcely formed, were soon invaded, and made to assist in forming other strata. Every particle, as if caught in an eternal eddy, never ceased to wander from rock to rock; and consequently, continental masses, which are, indeed, nothing but vast agglomerations of particles, must have incessantly shifted their positions on the circumference of the globe.

It would be of the highest scientific interest if we could follow, from age to age, all these shiftings of the outward features of the earth's surface, and the oscillations of their relief from century to century. The harmony of the continental structure, even now so beautiful to contemplate, notwithstanding the apparent immobility of its outline, would assume a different kind of grandeur if

one could see with the mind's eye the infinite succession of undulations which have rippled the surface of our planet. Unfortunately, although the direct investigations of geologists can point out to us those portions of our present continents which emerged at any particular epoch, they cannot disclose anything to us as to those regions which, although now buried by the sea, were once elevated above its surface. Therefore the charts which are prepared of any geological period can only be partial; but still, these charts, incomplete though they may be, are none the less an admirable result of ingenious and patient investigation. It is beautiful, after an unknown lapse of centuries, to be enabled to recognise, among all the various continental regions, those which were raised above the sea at the same epoch, and thus dimly to trace out some of the features of the ancient architecture of the globe.

The fault of many geologists, in their too great hurry to fix the commencement of the present period, has been that they have looked upon these first beds of our continents as being the only land which existed at this epoch of our planet. It is quite possible that there was a time when the whole surface of the globe was covered with water, and that the first land was nothing but a mere shoal; then, perhaps, that islets and then islands made their appearance, and, grouping themselves into archipelagos, ultimately united into continents. But nothing warrants the idea that during the formation of the strata examined by geologists the proportion between land and water has sensibly changed. Fresh land may have risen up at points where an examination of the strata proves that the ocean once flowed; but to make up for this, there are numbers of facts which bear witness to the disappearance under the water of vast tracts of country. Age after age the general plan of continents has been continually modified; our plains, and even our very mountains, have been covered with the waters of the sea; whilst chains of hills and plateaux rose high up in latitudes of the globe where the waves of the ocean are now rolling. In order to ascertain approximately the former extension of continents across our present seas, geologists have one means at their command—that of establishing the perfect harmony of the various strata of a formation broken through and disconnected by the waves. For instance, between France and England, the corresponding character of the strata on the two shores of the Straits of Dover is plainly evident, and thanks to the determination of this geological fact, engineers have confidently undertaken the task of connecting both sides of the channel by a tunnel through the chalk formation under the bed of the sea.

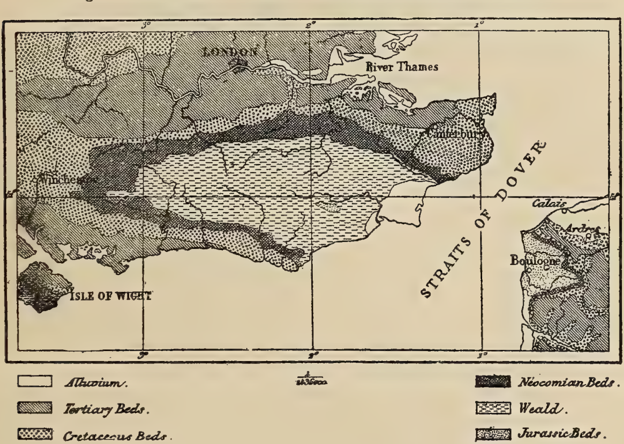
The fossil remains which are found accumulated at certain spots in the earth whither the currents have borne them likewise prove the ancient extent of some countries which are now reduced to very small dimensions. Thus, Attica, which in the present epoch is a mere rocky promontory of the Greek peninsula, must certainly in the Miocene period have formed a part of a continent presenting vast plains, wide-spreading grassy prairies, and thick forests, which must have extended across the space now occupied by the Archipelago and a portion of the Mediterranean Sea, stretching away far enough to unite itself to Africa. This is the tale told, in a way evident enough to geologists, by the remains of gigantic animals found in the Pikermi deposits. The droves of hipparions, like those of the wild horses of South America, the flocks of antelopes of various species, the tall giraffes, the mastodons, the rhinoceros, the powerful dinotherium, the formidable machairodus, stronger than the lion of the Atlas, and so many other animals of large size, the fossil bones of which are kneaded into the soil, could not have existed on mountains either entirely bare or thinly sprinkled with scanty shrubs, and in the

narrow valleys which form the Attica of our day. No, they required a vast continent like that of Africa, where we still see, in the portions not yet invaded by the white man, such prodigious multitudes of hippopotami, elephants, antelopes, zebras, and buffaloes.

The fossils of the two series, animal and vegetable, serve to prove still more directly the former existence of lands which have now disappeared. In fact, if we find the same fossil species in the corresponding geological strata of islands and continents which are at present separated by arms of the sea, and subject to different conditions of climate, we may naturally conclude that the regions in which these species existed were once united. A harmony of this sort between the Fauna and Flora has enabled geologists to establish the fact of the former existence of land joining England and Ireland, Ireland and Spain, and even Europe and America.

In exploring the lignite beds of the Tertiary formation in Europe, geologists have, in fact, found fossil tulip-trees, the remains of the Louisiana cypress (*Taxodium*

Fig. 5.—The Weald of Kent and the opposite French Coast.



distichum), seeds of the Robina nuts of a United States species, leaves of the maple, oak, poplar, pine, magnolia, sassafras, and taxus; also of the sequoia—those giants of the Californian forests—and other North American trees, which do not now exist in European forests. Half-way between the two continents, the lignites of Iceland present an analogous fossil vegetation. Unless a continent, or at least a series of adjacent islands, had served as a bridge across the wide Atlantic, how was it possible for these American trees to have invaded the land of Europe? In the same way, in the Miocene strata of Nebraska, remains have been found of the rhinoceros, the machairodus, and the palæotherium—that is, exactly the same animal fossils as in the corresponding beds in Europe. The former existence of an identical system of organic life in two continents, now so entirely distinct in their Fauna and Flora, gives us the right to assume that, at the epoch of the Tertiary lignite, the scattered lands and the few clumps of mountains which formed, as it were, the rudiments of our Europe, were connected with the American coast by an isthmus, separating the

waters of the Atlantic from those of the Frozen Ocean. This isthmus was the Atlantis, and the traditions which Plato speaks of about this vanished land were perhaps based upon authentic testimony. It is possible that man may have witnessed the submergence of this ancient continent, and that the Guanches of the Canary Islands were the direct descendants of the earliest inhabitants of this primeval land.

At a still more ancient epoch, when the fossils which are now found in the beds of the Jura formation were still being deposited at the bottom of the sea, the Atlantic was in existence, but of very different dimensions. It would appear that during these ages of the earth's history, a vast continent, including the two Americas, Africa, the Indies, and New Zealand, extended in an oblique direction as regarded the equator, between the two great oceans of the north and south. This continent, which, like the land at the present time, covered scarcely a third of the surface of our planet, separated by its enormous mass many of those gulfs in which the remains of organized beings were being deposited; this is proved by the fact that the Jura formations of Texas, in the same latitude as those of southern Europe, do not present, among the few fossils they contain, the remains of those numerous species of the Old World which, like their congeners of the present epoch, travel to very considerable distances. If there had been no obstacles between the two basins, this absolute contrast between the two Faunas would have been impossible. In the same way, the species of the Jurassic formations of South Africa are completely different from those of the Himalaya, Persia, and Europe; this must lead to the admission of the former existence of an intervening continent which prevented the migration of living creatures. Finally, the Australia of our own days presents, both in its Flora and Fauna, the very greatest similarity to the animals and plants which lived in the Jurassic seas of Europe and on their shores. In looking at the kangaroos of Australia, which remind us of the marsupials of the Jurassic formations of England, and the strange ornithorhynchus, scarcely less fantastic in its shape than the ancient pterodactyle, half bird, half batrachian, or than the problematical *Archæopterix* of Solenhofen, one can hardly refrain from the belief that Australia once formed a part of the ancient Jurassic continent. Besides, the coast of New Holland is the place where we now find the only living representatives of *Trigonia,* which once inhabited the Jurassic seas.

Round the inland sea which has now become our present Europe, the great continental mass threw out a large, crescent-shaped peninsula, at the origin of which was the mouth of a considerable river, the delta of which may still be traced out from the coast of the English Channel as far as Westphalia. On the sheet of water which this peninsula protected from the freezing winds of the polar zone, warmed, too, as it was, by the heat of the equatorial lands, the mean temperature must have been much higher than it now is in the corresponding portion of the earth; it was, without doubt, more than 68° Fahr., if we may judge by the presence of the ichthyosaurus and plesiosaurus. It must, however, be understood that the outlines and various conditions of these long-vanished regions are still very far from being known with any degree of certainty, and it will perhaps require centuries of investigation before a chart of the Jurassic continent can be satisfactorily drawn up.

Circumstances, very similar to those which have enabled us to form some approximate idea as to the temperature of Europe in the Jurassic period, have also permitted *savants* to venture on some general indications relative to the fluctuations of climate which are presented by the other great periods in the earth's history. Thus, the mean temperature of Europe was first mild; then, during the

Silurian ages, it became gradually raised; in the period of the Carboniferous formations the climate was very warm and very damp, because the greater part of the land, then mostly situate in the torrid zone, consisted of an uninterrupted series of archipelagos. The epoch of the Trias was comparatively cold, on account of the great extension of the continents towards the poles. After the ages of the Jura formations, which were very warm and very dry, came in succession a temperate period, that of the Chalk; then an epoch of heat, the Eocene; and then times of cold, gradually increasing up to the Glacial period; after which the temperature again increased. This is a very brief abstract of the succession of climates in the region which is now Europe, following the inferences which Lyell, Marcou, Oswald Heer, and other *savants* have drawn from the facts which they have observed and carefully classified.

We thus see what grandeur there is associated with the labour of the geologist. Starting from the increasingly profound study of the present strata, the science of geology has adopted as its task to reconstitute the varying forms of continents and seas in each of the successive periods of the history of the globe; it follows out, in the various epochs, the courses of the winds and the currents, which also have shifted with the continents themselves; it endeavours to measure, as if with the thermometer, the temperatures which have prevailed in different ages in the various countries of the earth; finally, it seeks, by all the connecting links which the scattered *débris* can afford, to trace out the marvellous filiation of animal and vegetable species, from the earliest fossils—of which all that has been discovered is but a faintly marked impress—down to the innumerable beings which now stock our earth. Still dissatisfied with the ideal she has aspired to, science entertains the hope that she will one day be able to point out the exact conditions under which every organism was developed in the periods gone by, and that she will be able even to specify, as regards fishes, shells, and seaweeds, the depth of the water in which these beings once lived. The astronomer explores the boundless infinities of space; the geologist penetrates into the abyss of time.

The investigation of various rocks testifies more and more to the prodigious activity of the forces which are ever remodelling the earth. Just as our planet, like all its sister orbs and all the stars of heaven, is borne on in eternal motion, so all the particles composing the mass of the globe are incessantly changing their place, and are circulating without repose in a cycle no less harmonious than that of the heavens. In the first envelope of the earth, the atmospheric ocean which sustains the life both of animals and plants, continual eddies of winds, blowing from the pole and the equator towards all points of the horizon, are incessantly circulating. In the great ocean, too, of waters, every drop also rolls on from sea to sea, and from the wave is borne up to the cloud, and from the cloud descends to the river. The so-called solid portion of the planet is not less mobile than the atmosphere and the water, though the shifting action of its particles is slower. Sometimes, perhaps, when in a short interval of days, years, or centuries, man has failed to see any vast modifications accomplished, he is tempted to say that the earth is immutable. Was there not a time when he also designated as *fixed stars* those distant luminaries, which nevertheless move through ether with so prodigious a rapidity?

Rocks, mountains, and continents are all in a perpetual state of change, and their particles move round and round the globe like the water and the air. By the action of torrents and atmospheric agencies, mountains are crumbled down and carried away into the ocean; new regions are upheaved out of the water, whilst

others slowly sink and are finally submerged; the earth itself is rent open, and gas and the molten matter of vast strata make their escape. Finally, in consequence of the incessant chemical reactions going on within the bowels of the earth, the composition of the rocks themselves is changed, and growths of crystals follow one another in the metamorphosed stone, just as the Fauna and Flora on the soil above. An exchange of matter is likewise going on between the earth and the celestial spaces, as is proved by the trains of burning stones which become detached from meteoric bodies rushing through the atmosphere; and the tails of comets, through the invisible waves of which the earth occasionally passes. Planetary vitality, like every other vitality, is a continual *genesis,* an incessant eddy of particles, at one time fixed, at another free, which pass from one organism to another. Nevertheless, in whatever aspect of its infinite modifications the earth is contemplated, it is ever beautiful in its form, and its consecutive phenomena take place with a marvellous harmony.

Physical geography, in confining itself to the present epoch, merely describes the earth as it is existing before our eyes. Its aim is not so ambitous as that of geology, which tries to recount the history of our planet during the long succession of ages; but still, it is geography which collects and classes the facts; she it is that discovers the laws both of the formation and the destruction of strata. She opens out a path for geology to travel over, and each of her advances in the knowledge of existing phenomena helps to render easier some victory of the human intellect over the past history of the globe. Without her aid, it would have been impossible even to have ventured the initiative step into the labyrinth of vanished ages.

Part II.

THE LAND.

CHAPTER VI.

REGULAR DISTRIBUTION OF CONTINENTS.—IDEAS OF ANCIENT PEOPLES ON THIS POINT.—HINDU LEGENDS.—ATLAS AND THE GIANT SHIBSHACUM.—HOMER'S SHIELD.—STRABO.

THE globe of our earth is in evident conformity to all the laws of harmony, both in the spherical uniformity of its shape and also in its constant and regular course through space. It would, therefore, be incomprehensible if, on a planet so rhythmical in all its methods, the distribution of continents and seas had been accomplished, as it were, at random. It is true enough that the outlines of coasts and mountain ridges do not constitute a system of geometrical regularity; but this very variety is a proof of a higher vitality, and bears witness to the multiplicity of motions which have co-operated in the adornment of the earth's surface.

The uneven and yet harmonious configuration of the continents is, as it were, the visible representation of the laws which, for a long series of centuries, have ruled in the external modelling of our planet. "There is not a fundamental line in the outline of the earth which is not a line of geometry."

So long as the greater part of the surface of the globe was unknown to geographers, and they were ignorant of the true form of the earth, it may be easily understood that man, embracing in his feeble glance but a limited horizon, should have recognised nothing but chaos in the intricate network of geographical lines. It was impossible for them to take into account the laws which had influenced the distribution of continents, because they were ignorant of their very outlines; as the analysis of the various terrestrial forms was not yet completed, they were of course unable to accomplish the synthesis of them, except by making unproved assertions, or by speculations in miraculous cosmogonies.

At all events, nations in their infancy, being well assured beforehand of the vitality of the bountiful earth which supported them, have without exception looked upon nature as an immense organism endowed with supreme beauty. For some, nature was an animal; for others, she was a plant; for all, she was an incorporated god. The ideas which they formed on this point are in general the

most precious matter which is handed down in their traditions, either oral or written; for in these legends, in which they display the loftiest manifestations of their poetical genius, they sum up their persuasions as to the origin both of the earth and also of their own race. For the comparative study of the history, manners, and ideal of every nation, no book could be more useful than one which would contain all the cosmogonical conceptions which have been devised, down to our own times. But, as may easily be understood, these legends are more simple and rudimentary in their nature just in proportion as the cosmical features among which they were conceived, and of which they are in a great part the reflection, were more subdued in their manifestations and phenomena. The people of the extreme north, who are in the habit of digging out subterranean habitations in order to avoid the cold, their country being for a great part of the year covered with ice and snow, cannot have their ideas as to the harmony of the globe inspired by the same conceptions as the men of the south, who dwell at the foot of the highest mountains in the world and constantly contemplate all the great phenomena of planetary life—monsoons, hurricanes, the sudden overflows of rivers, and the rapid increase of immense tropical forests. To the Hindus everything in nature is motion, never-ceasing creation, and startling activity. According to one of their books, Brahma, the eternal labourer, created the earth whilst surveying his own reflection in the ocean of sweat that had fallen from his brow.

The Hindu legends as to the formation of the earth and the distribution of continents are very numerous; besides, most of these hypothetical cosmogonies are remarkable for their boldness and for the deep conviction they manifest of the vitality which animates the earth, and all that it contains. However strange some of these grandly poetical theories may seem to us, they are not on this account any less true than the dry systems of mere nomenclature in which certain unhappy scholars have considered the whole scheme of geography. According to an ancient Hindu belief—very similar to that of several of the American nations—the earth is nothing but a burden placed on a gigantic elephant, the symbol of intelligence and wisdom; whilst an immense tortoise, representing the still rude forces of nature, bears the enormous animal over a shoreless sea of milk, boundless as infinity.

Subsequently, the ideas which the Hindus formed as to the origin of the globe were singularly diversified, according to the various epochs and sects. The Brahmins fancied that the earth was a full-blown lotus, floating on the surface of the waters. The two peninsulas of the Ganges and the other Asiatic countries are the expanded flower, the isles scattered over the ocean are the half-opened buds, distant lands are the softly spreading leaves. The Ghauts and the Neilgherries are the *stamens* of the immense flower, whilst in the midst culminates the lofty Himalaya, the sacred *pistil*, in which are organized the seeds of the world. Man, like the tiny insect which sees infinity in a rose, builds his imperceptible cities near the honey-cups of the flower, and sometimes spreads his wings to glide over the sea from the *corolla* of the Indies to that of Ormuz or Socotora. The stalk of the plant disappears in the depths of the ocean, and descending from abyss to abyss, at last buries itself in the very heart of Brahma.

This fantastic, but yet somewhat grand, conception, which at least attributed to the earth some degree of motion and life, is very superior to all the dogmatic theories of the Syrian priests and the Hebrew Talmudists. The latter, in their dread of change, looked upon the terrestrial mass as an immovable block solidly based on immense columns of stone or metal, which were themselves lost in primi-

tive chaos. These ancient and coarse hypotheses are met with again in the more noble myth of the Greeks, according to which the globe was placed upon the shoulders of a kneeling giant. This was an idea which was in full harmony with the plastic genius of Greece, which ever sought to recognise in everything the proportions of the human form, deified, as it was, by strength and beauty. The idea, in the main, had remained much the same; but it had assumed a shape which was more poetic, and consequently more in conformity to the genius of an infant nation. Imbued with similar ideas, the aborigines of the plateau of Bogota tell how, in punishment for some crime, the good goddess Bochica condemned the giant Shibshacum to bear upon his shoulders the burden of the earth, which

Fig. 6.—The World after the Poetic Accounts of Homer.

previously rested upon pillars of *lignum-vitæ* wood. Earthquakes, therefore, were derived from no other cause than the wearied or impatient movements of this Atlas of the New World.

With regard to the ideas in respect to the distribution of continents and seas over the surface of the globe, they could hardly fail to be erroneous, inasmuch as they took their rise among nations who endeavoured to form a judgment as to the whole of the earth by means only of the few countries which were known to them.

According to the poems of Homer, which are imbued with the ideas of the ancient Greeks as to nature, and also mankind and their ways, the earth is a great disc, elevated at the edges by a lofty girdle of mountains, round which the river Ocean rolled its swelling waves. In the centre of the disc, Olympus towered up

with its three rounded summits, on which stood the mansions of the ever-happy gods, and Jupiter, throned on its loftiest crest, looked down through the clouds and saw the restless crowd busy at his feet. The land, divided into two parts by the blue sheet of the Mediterranean, stretched far away to the very verge of the disc, like the raised figures which ornament the front of a shield. Down from the heights of Olympus the immortals contemplated in one glance all the peninsula of Greece, the white isles of the Archipelago, the coasts of Asia Minor, the plains of Egypt, the mountains of Sicily, inhabited by the Cyclops, and the Pillars of Hercules—the boundary-stones of the ancient world. All round, above the tract inhabited by man, stretched the crystal dome of the firmament, borne up by the two columns of Atlas and Caucasus.

But the discoveries of travellers and the calculations of the Greek astronomers must have gradually modified this primitive theory. Strabo, who was, however, one of the greatest travellers of antiquity, having traversed the earth from the mountains of Armenia to the shores of the Tyrrhenian Sea and the Euxine, and to the frontiers of Ethiopia, had already formed a very just idea of the real distribution of the continents of the ancient world, and discussed with wonderful sagacity their mutual relations. Overstepping the limits of the regions already known, he went so far as to hazard the assertion that, between Western Europe and Eastern Asia, there existed an inhabited land forming an equipoise to the Old World. In all his scientific audacity, he conjectured that which modern geography has since discovered—that "not only mere masses of rock and islands, large or small, but also whole continents, may be upheaved from the bed of the sea." As the great Ritter has stated, with a feeling which may almost be called filial, Strabo is the real founder of geographical science, and modern *savants* have only resumed his work, after so many centuries smitten with sterility, first by the Roman Cæsarism, and subsequently by the barbarism of the Middle Ages.

CHAPTER VII.

INEQUALITY OF LAND AND WATER.—THE OCEANIC HEMISPHERE.—THE CONTINENTAL HEMISPHERE.—THE SEMICIRCLE OF LAND.—DISTRIBUTION OF THE HIGHEST PLATEAUX AND LOFTIEST MOUNTAIN-CHAINS ROUND THE INDIAN AND SOUTHERN OCEANS.—POLAR CIRCLE.—CIRCLE OF LAKES AND DESERTS.—COASTS ARRANGED IN ARCS OF A CIRCLE.

THE most prominent fact which strikes an observer in an examination of the superficies of the earth is the unequal extent of the ocean and of the land which has emerged from it. Although at the two polar regions there are still vast unexplored tracts forming about a sixteenth of the terrestrial surface, still it may be approximately stated that three-quarters of the surface of the globe is covered by water. The plate gives an idea of the distribution of land and sea in the explored

Fig. 7.—Relative Proportions of Land and Water in different Latitudes.

regions of the globe from 75° north latitude to 70° south. An equilibrium between the two elements exists only on two parallels of the terrestrial circle, one of which is in 45° of north latitude, half-way between the equator and the pole. In this part of the earth's circumference the land occupies exactly one-half of the surface of the globe.

The principal accumulation of water is in the southern hemisphere, and the

continental masses, on the other hand, are grouped in the northern half of the earth's surface. This contrast between the two divisions of the globe becomes much more striking if, instead of taking the two poles as the centres of our hemispheres, two points are chosen which are situated, one in the midst of the most extensive tracts of ocean, and the other about the centre of the group of continents. If we describe a great circle round London, which at the present time is, in fact, the great focus of attraction for the commerce of the whole world, almost all the continental surface surrounding the basin of the Atlantic, rendering it almost an inland sea, will fall within this hemispere. The other half of the terrestrial surface, the centre of which would be situated somewhere near New Zealand, the

Fig. 8.—Oceanic Hemisphere.

antipodes of Great Britain, is almost entirely filled up with the immensity of water. The antarctic countries—Australia, Patagonia, and the adjacent archipelagos—form the only land which breaks the uniformity of this oceanic hemisphere. According to a very plausible hypothesis, this exuberance in the development of continents on one side of the globe, and the afflux of the waters of the ocean towards the opposite hemisphere, are caused by the unequal weight of the materials which constitute the mass of the globe and the consequent non-coincidence between the actual centre and the centre of gravity.

The coast outline of the continents which surround the great ocean tends to a form which is perceptibly circular; it is a kind of ring, broken in two at the south near the frigid zone of the antarctic circle. From the southern point of Africa to

Kamchatka, and from the Aleutian Isles to Cape Horn, the land is arranged in an

Fig. 9.—Continental Hemisphere.

immense amphitheatre, the circumference of which is equal to the circumference of the globe, and cannot be less than 25,000 miles. They are not merely low

Fig. 10.—Basin of the Pacific.

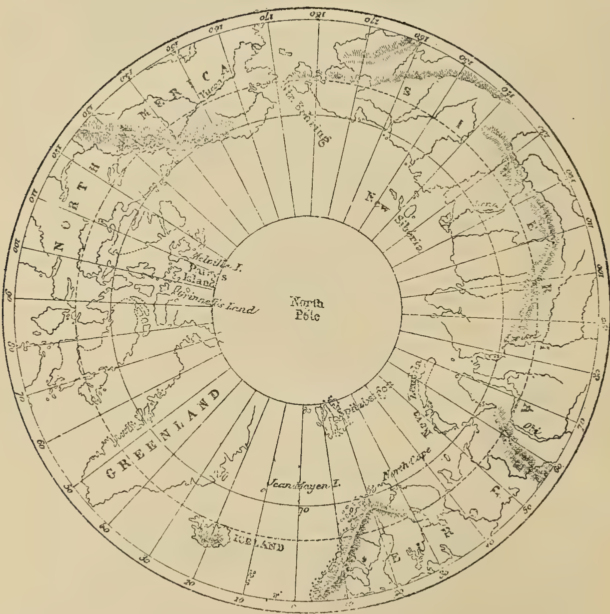
shores which spread in this hemicycle round the oceanic hemisphere ; the highest plateaux, the loftiest mountains of the world, are drawn out in a vast semicircle in

those countries which are adjacent to the Pacific, and tend to incline towards that ocean the centre of gravity of the whole of the continental bulk.

Thus it is along the side of the Indian Ocean, an appendage as it is to the great Southern Ocean, that Africa presents its loftiest ridges; there, too, are found the snowy mountains of Kenia and of Kilimanjaro and the plateau of Abyssinia, like a great fortress surrounded by bastions. Eastward of the narrow entrance to the Red Sea stands another plateau, that of Yemen, whose steepest slopes are likewise turned towards the shores of the ocean.

Farther on, this rampart of lofty ridges, which might well be called the "vertebral column" of the body of continents, is interrupted by the depression of the Euphrates and the Persian Gulf; but it again commences at the north of

Fig. 11.—Circumpolar Circle.



Persia. The Caucasus, the Elburz, the Hindu-Kush, the Karakorum, and the proud Himalaya, the summits of which rise more than $5\frac{1}{2}$ miles above the plains of Hindostan; all are, on an average, three or four times nearer to the Indian than to the Arctic Ocean. This difference would be still more increased if we did not take into account, as portions of the great Asiatic body, the southern peninsulas which stretch away so far into the sea. Taken as a whole, the continental mass may be divided into two gradients, one of which descends rapidly towards the plains next the Indian Ocean, whilst the other side, ribbed with divergent mountain chains, inclines more gradually towards the immense marshy *tundras* which border the Frozen Ocean.

The great plateaux of Central Asia, bounded on the north and south by the mountain chains which radiate in a fan-like shape from the knot of the Hindu-Kush, form, in the direction of the north-east, the highest portion of the continental amphitheatre; then, in the north of the valley of the Amour, they are prolonged up to a short distance of the coast-line by ranges of peaks, which tower over the Sea of Ochotzk and Behring Straits. Beyond this the waters of the Pacific have opened out a passage to join the tides of the Frozen Ocean; but yet the line of mountains is still prolonged. Arranged, as they are, in the form of a broken isthmus, on the south of the straits, the Aleutian Isles unite the two continents of

Fig. 12.—Circle of Inland Lakes and Seas.

Asia and North America; one might almost fancy them the shore-line of some ancient and submerged land.

The lofty peninsula of Alaska, which follows on to the Aleutian range, is the starting-point of the series of highlands which border the coasts of the Pacific along the whole length of the two American continents. Parallel chains, abutting in some places on large groups of mountains, bend round the shores of Sitka, British Columbia, and California, gradually merging into the plateau of Anahuac. The latter is prolonged on the south-east by a volcanic chain, here and there interrupted; but on the coast of the Gulf of Darien the great chain begins again, and, plunging the rocks which form its base deep into the waves of the Pacific, extends its double or triple snowy ridges down to the Straits of Magellan. The other elevations of the surface of the ground lie to the east of this backbone, as it were,

of the South American continent, and attain a very much less considerable altitude; they are, indeed, intersected and even crossed by some of the rivers which take their rise in the perpetual snows of the Andes. Added to this, the steepest slope of the principal chain is uniformly turned toward the coast of the Pacific, and the distance from the mouths of the Amazon to the summits of the Andes is, on the average, at least fifteen times longer than the short span from the ridges of the latter to the shore of the ocean.

The immense semicircle of high land forming the inner coast-line of the mass of continents which extend from the Cape of Good Hope round to Cape Horn is not, however, the only evidence of the forces which are always in action, tending to elevate the salient portions of the terrestrial sphere, and operating in great circular lines. Thus in the chain of the Andes is commenced a series of volcanic

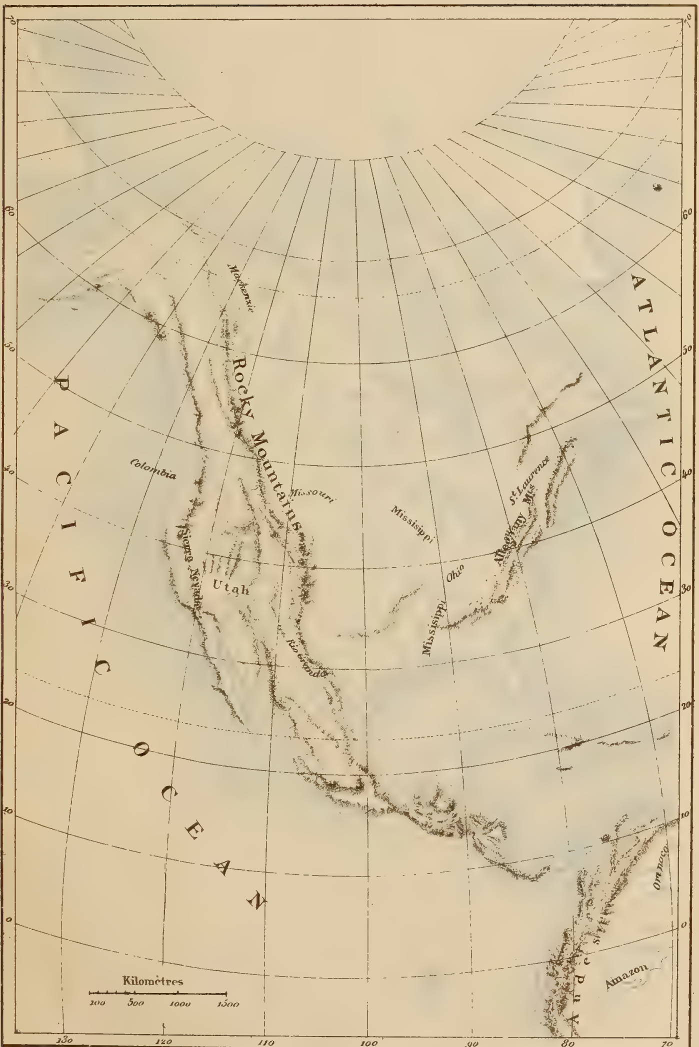
Fig. 13.—Semicircle of Deserts.

mountains and islands which forms a vast circle round the Southern Ocean. This is the great ring of active volcanoes, which was for the first time described by Leopold von Buch, and designated by Carl Ritter as the "Circle of Fire."

Thus, also, the continental and insular shores which are turned towards the Arctic Ocean assume a circular curve. As far as it is possible to judge from the present state of our knowledge as to this part of the world, it appears as if a polar circle inclined about five degrees towards Behring Straits would have for its almost regular circumference the northern coasts of Siberia, of Parry's archipelago, Greenland, Spitzbergen, and Nova Zemlya.

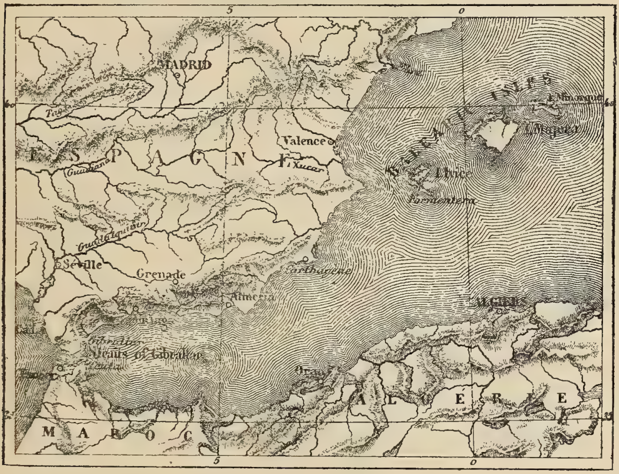
Another circle, inclined about ten degrees to the pole in the direction of the meridian of Paris, would pass through the greater part of the inland seas of the Old and New Worlds. This curve would enter the Mediterranean through the

NORTH AMERICA



Straits of Gibraltar, and crossing this sea, as well as the Euxine, would unite the Caspian and the Sea of Aral, both of which, during a recent geological epoch, formed but one sheet of water; it would then be prolonged towards the Pacific through the chain of the chief Siberian lakes, including the Baikal. On the American continent, the curve passes through Lake Winnipeg, the Mediterranean of the great lakes of the St. Lawrence, then Lake Champlain, and the Bay of Fundy. Thus terminates this great series of continental depressions, which certainly was not formed at random. On the north of the Mediterranean, the most important of all the inland seas, the loftiest mountains in Europe form a rampart similar to that which bounds the South American shore of the Pacific. In fact, the Pyrenees, the Alps, and the Balkans form a sort of wall, broken through

Fig. 14.—Western Shores of the Mediterranean.



with numerous gaps, which is much nearer to the Mediterranean than to the northern seas, and presents also its steepest slopes towards the south.

Jean Reynaud has also thought that he could point out the existence of another terrestrial ring, which must likewise have been formed in obedience to some great geological law. This third circle, inclined 15° (or rather 20°) to the pole, passes through the Isthmus of Panama, which is the deepest depression of the land of America, and crosses almost all the great deserts in the Old World, many of which were covered with water during the later terrestrial periods. These sandy or rocky tracts are arranged obliquely across the continents of Africa and Asia, and consist of the Sahara, the sandy districts of Egypt, the Nefud of Arabia, the salt plateaux of Persia, and the Gobi, or Shamo, the latter inferior in extent only to the African solitudes. It is a remarkable fact that this series of dried-up seas is commanded on the north by various mountain chains, the Alps, the Taurus, the Caucasus, and the Altaï; like the Pacific and the Mediterranean, these now vanished waters were bordered on the north by a rampart of high lands. Oscar Peschel has, however, proved that the phenomena of climate constitute the real cause of the

supposed "Equator of Contraction;" and that this semicircle of deserts is to be attributed to the general direction of the winds and the scarcity of rain.

Not only those various regions which are distinguished by some striking analogy in elevation and aspect are circularly arranged on the surface of the planet, but the mere outlines of the continents themselves seem to be obedient to some rhythmical law, in conformity to which they present a series of arcs of a circle, assuming a regularity which is sometimes almost perfect. The coasts of the three southern continents, South America, Africa, and Australia, afford remarkable instances of this rule. The coast-lines of all the peninsulas of the northern continent may likewise be cut up into arcs of a circle, and multitudes of islands, of which Sicily can perhaps be taken as a type, may be compared to actual curving-sided triangles. This circular arrangement of the coasts is so frequently remarked, that many geologists have gone so far as to endeavour to class various countries according to the degree of the curvature of their gulfs and bays.

CHAPTER VIII.

DIVISION OF THE LAND INTO THE OLD AND NEW WORLDS.—DOUBLE AMERICAN CONTINENT.—DOUBLE CONTINENT OF EUROPE AND AFRICA.—DOUBLE CONTINENT OF ASIA AND AUSTRALIA.

ALTHOUGH we may consider the continental masses as arranged in certain great circles traced round the sphere, we must also recognise the effect of another law, in virtue of which the various groups of land are arranged in three double continents, forming respectively three parallel series.

At first sight it would seem as if the portions of the earth which have emerged from the waters form, in fact, but two groups—those of the Old and New Worlds—and that the shapes of these groups appear to bear little or no resemblance to one another. Yet a careful examination cannot fail to reveal a striking unity of plan, where at first sight all seems disorder and chaos. The fact is, in consequence of the crossing of the different upheaved portions of the earth—some in a circular direction round the seas, others parallel to the meridian—there is produced among the continental groups a series of contrasts which so interfere with the resemblances that, in the general distribution of the land, opposite forms become successively predominant. Nevertheless, this medley, by its infinite variety, is the very thing which gives so great a harmony to the *ensemble* of the terrestrial outline.

In the comparative study of the configuration of continents, we must choose America as our type, because in this portion of the world the line of upheaval, tending from north to south, forms a tangent to the curve which is described by the disposition of the land round the Pacific, and is even coincident with it along a certain portion of its extent. In consequence of this coincidence of the axis the New World exhibits a very great regularity of shape. It is composed of two triangles, each pointing its apex towards the south, and linked together by a very narrow isthmus. These two sections of America, one of which belongs entirely to the northern hemisphere, the other being tropico-meridional, form two perfectly distinct continents, and yet they show so great a similarity of structure that they are evidently the counterparts of one another. Nevertheless, as the natural effect of the increasing divergence in North America between the continental axis and the circle of mountains which spread round the Pacific, this continent is much larger than its companion, and its coast-line is much more indented. The more typical form, therefore, is that of the southern continent.

In the Old World, Africa evidently follows the same model as South America.

As regards their general structure, the two continents are alike in their great triangular mass, with coasts slightly inflected; and the similarity extends even to the details of their gulfs and promontories. The contrasts are, it is true, very numerous; but they exhibit so much regularity and rhythm, so to speak, that even in these we cannot fail to see a new proof of unity of formation in the two continental masses.

As far as Europe is concerned, we should, at first sight, be tempted to say that there was no degree of correspondence between this part of the world and the North American continent. In fact, this collection of peninsulas, which even in our days is still the most important region of the whole world on account of the high civilisation of the nations inhabiting it, might be looked upon as nothing but a geographical appendix—a mere prolongation of Asia; in fact, we almost hesitate to compare it with North America, the bulk of which occupies a superficies twice as large. Yet a geological study of the conformation of Europe proves that in reality it forms a distinct continent. At some previous epoch it was separated from Asia by a sheet of water, which stretched from the Mediterranean to the Gulf of Obi, through the present Euxine, Caspian, and Aral Seas. At the foot of the Ural and Altaï mountain chains extend those immense steppes which, like most deserts, still retain much of their former oceanic appearance, and form the eastern boundary of Europe quite as effectually as would a second Atlantic. The arm of the sea which once divided these two divisions of the world is, indeed, dried-up; but, although now united, the two lands none the less retain their distinctly defined characters.

Thus geology bears its testimony in establishing the continental form of Europe and its similarity to North America. The resemblance between the two quarters of the globe is kept up on the southern as well as on the eastern side. It is very true that on the southern side the land of Europe is no longer connected with that of Africa by an isthmus similar to that which joins the two Americas; but, as even Strabo well knew, an upheaving of scarcely a hundred yards would suffice to form a tongue of land from Sicily to Tunis, dividing the Mediterranean into two sections. A submarine bank separates this sea into two deep basins, and, owing to its steep elevation, may be considered as an actual isthmus. Added to this, the northern part of Africa—that is, the region of the Atlas, comprised between the former sea of the Sahara and the present coasts of Morocco, Algiers, and Tunis—is certainly an ancient dependency of Europe. Modern science has established the fact that, as regards both its Fauna and its Flora, as well as its geological constitution, the whole of the eastern sea-coast of the Mediterranean—the north, as well as the south—forms an inseparable whole. Thus M. Bourguignat has clearly shown, by his examination of living molluscs, that Northern Africa does not possess one single species which is peculiar to it, and that all the types of the animals which are found on the slopes of the Atlas proceed from the Iberian peninsula. The Western Sahara and Tripoli being equally devoid of any species specially belonging to them, it becomes evident that these latter regions at the commencement of the present epoch had not yet emerged from the bed of the ocean, and that Mauritania formed the southern continuation of the Spanish peninsula; the headlands of Ceuta and Gibraltar then formed portions of one and the same chain of mountains. The ancients were not ignorant that the western entrance to the Mediterranean had once been closed, since they attributed to Hercules the honour of having opened the gate between the two seas. Many authors even regarded it as a vexatious innovation that the geographers had made Europe and Libya two distinct parts of the

Orenoco
Magdalena
Amazons
Rio Negro
Amazons
Madeira
Tocantins
Sn. Francisco
Paraguay
Parana
Parana
Rio de la Plata
ANDES
ANDES
PACIFIC OCEAN
ATLANTIC OCEAN
Kilomètres.
100
500
1000

world; for although separated by the sea, the two regions appeared to them to belong to the same geographical whole.

The external outlines of Europe remind one forcibly of those of Northern America. In both continents the coasts which border on the Atlantic are deeply indented, and not only allow the sea to penetrate a long way into the interior of the land in various places, but also throw out peninsulas far into the ocean. In Europe, the Mediterranean and the Baltic Sea correspond with the Gulf of Mexico and all those seas which extend between Greenland and British America. But it must be remarked that in Europe, the arrangement of which is finer and more delicate than that of any other part of the world, the peninsulas are more slender in form, and the inland seas more surrounded with land. In Europe the peninsulas have become islands and the seas have become lakes. Nevertheless, Europe corresponds in its structure with North America to a great extent, and forms, with Africa, a second pair of twin continents, parallel to those of the New World.

Asia and Australia constitute the third pair of continents, although their form only very imperfectly reproduces the primitive type. There is an interruption of equilibrium to the great advantage of the northern portion; but in the general configuration of these great masses we can still discern the principal features which distinguish the other double continents. Like North America and Europe, Asia is

Fig. 15.—Terra Quadrifida.

Fig. 16.—Mundus Tripartitus.

geologically isolated; like these two parts of the world, she throws out numerous peninsulas into the seas which surround her; and although she is not directly united to Australia by a continuous isthmus, yet the Sunda Isles, "like the piles of a demolished bridge," stretch across the seas between the two continents. As regards Australia, both by its regular and almost geometrical form, and also by its entire absence of peninsulas, it evidently reminds us of the two other parts of the world which push their way far into the Southern Ocean.

Finally, if we consider separately the Old World, or eastern group of continents, we may recognise a quadripartite division, or the separation of the land into four parts arranged two by two on the north and south of the equator. This is the idea that was taught by most of the ancients, which also induced them to give to the world then known the name of *Terra Quadrifida*. Others, no less following certain systematic conceptions, fancied that the land that had emerged from the deep was shaped like an egg, and composed of three portions, surrounding the sacred temple of Delphi, "the *umbilicus* of the world."

Thus, in the external form of continents, we find two quite distinct laws in action; one, according to which they are arranged in circles obliquely to the equator, the other which distributes them in three lines parallel to the meridian. To this complication is due the apparent irregularity of the double continents in the Old

World, for there the two axes of formation cross, and consequently there also is produced a great diversity in the relief of the land. The mutual resemblances and contrasts exhibited by the two halves of the world can, however, be perfectly well explained if we connect them with one or the other of these two orders of facts. If we look upon the land as forming three parallel double continents, we must then be struck with the similarity which they mutually present both as a whole and in details; if, on the contrary, we admit the usual division of the continental masses into two worlds, we discern the reason of the contrasts, which are only another kind of resemblance. In this way we may explain the variety in the forms of the continent of Europe, by looking upon it either as the half of two twin continents parallel to the two Americas, or as a great Asiatic peninsula, forming a portion of the immense ring of land which extends round the ocean. Just as in a woven fabric, we can discern both the warp and the woof in the marvellous texture of the earth's surface.

The principal feature in the relief of the Old World is the enormous elevation of the land near the centre of Asia, at the intersection of the lofty chains of the Hindu-Kush, in that region of grandeur to which the epithet "the roof of the world" has been justly given. This elevated spot, round which radiate the Himalaya, the Karakorum, the Kuenlun, the Thian-Shan, the Soliman-Dagh, and other chains of mountains, is, in fact, the point of the earth at which the two continental axes cross one another, one tending from the north to the south, the other from the south-west to the north-east, parallel to the outline of the Pacific. At their meeting-point the two terrestrial waves overlap one another, just as two billows coming together in the open sea from two different points of the horizon. There, at the intersection of the axes, stands the real apex of the earth, the orographical centre of continents; there, too, we find, was the centre of dispersion of the Aryan nations. By a remarkable contrast, at the exact antipodes of this region of elevated plains and lofty mountains, we find those broad tracts of the Pacific which are most destitute of islands; and there, too, are probably situated the deepest profundities of the ocean.

CHAPTER IX.

PRINCIPAL ANALOGIES BETWEEN CONTINENTS.—PYRAMID FORM OF PORTIONS OF THE WORLD.—SLOPES AND DECLIVITIES.—CLOSED BASINS OF EACH CONTINENT.—SOUTHERN PENINSULAS IN EACH GROUP OF CONTINENTS.—HYPOTHESIS OF PERIODICAL DELUGES.—RHYTHMICAL ARRANGEMENT OF PENINSULAS.

EVERY continent, considered by itself, may be compared to a pyramidal mass having an enormous base and a summit placed far from the centre of its figure. Thus Mont Blanc, the loftiest summit of the Alps, is situated at a comparatively short distance from the west and south coasts of Europe. The latter, therefore, taken as a whole, may be looked upon as a pyramid, the height of which is not more than a thousandth part of its base; the faces turned towards Asia and the Frozen Ocean being four times as long, on the average, as the sides which tend towards the Atlantic and the Mediterranean. The Asiatic continent has for its apex the lofty mountains of the Himalaya, and from these elevated points the face of the country inclines in very different gradients towards the two opposite oceans: on one side the fall is rapid down to the plains and gulfs of Hindostan; on the other side the descent is very considerably longer.

The general outline of the relief of the continent of Africa is less known; it is, however, probable that the mountains Kenia and Kilimanjaro are the culminating points of the continental polyhedron. These mountains, which rise very far from the centre of Africa, also exhibit on one side a comparatively steep incline, and on the other a very gradual descent. In Australia we see the same phenomena, for the most elevated points of this continent are probably to be found in New South Wales, at a short distance from the edge of the Pacific; from these mountains to the Indian Ocean the distance is at least six times as great.

The two Americas, also, may likewise be considered as two solid bodies, having their culminating points far distant from the centre of the figure—one at Orizaba, or Popocatepetl, the other in the group of the Bolivian mountains. In spite of the varied outlines of relief which continents exhibit, in spite, too, of the basins and depressions in their surface, there are but few localities where the ground shows any hollows lower than the level of the sea; and these hollows, such as the neighbourhood of the Caspian and the valley of the Dead Sea, are situated precisely on the respective confines of two continents, Europe and Asia, and Asia and Africa. Even the depressions of the Algerian Sahara, the surface of which is in many places lower than the Mediterranean, are the bed of the ancient sea which once separated the real Africa from the districts of the Atlas.

Another great feature of resemblance between the various continental masses is

that each of them contains one or more closed basins, where a receptacle is found for the watercourses which cannot flow to the outer side of the continent; these cavities, having their own peculiar system of lakes and rivers, are, as it were, so many worlds by themselves. The Asiatic continent, the largest of all, and that in which the supposed centre is most distant from the sea, is the continent in which the inland hydrographical basins are of the greatest extent. They comprehend nearly the whole area of the high plateaux of Tartary and Mongolia, namely, the basins of Lob-Nor, Tengri-Nor, Koko-Nor, and Ubsa-Nor; and on the west of the great mountain chains of Central Asia they also embrace the plateau of Iran, the basin of Balkash, and also the basins of the sea of Aral and the lakes of Van and Urmiah. By the depression of the Caspian, the Asiatic series of lakes without outlet is connected with the European system, which extends to the very centre of Russia, to the sources of the Kama and the Volga. The whole of this region, the waters of which, from the hills of the Russian Valdai to the plateaux of Mongolia, find no outlet in the direction of the sea, embraces an area at least as extensive as that of Europe. The two continents of America likewise have their isolated systems of lakes and rivers occupying a corresponding position—one in the "Great Basin," between the Rocky Mountains and the Sierra Nevada of California, the other on the plateau of Titicaca, between the chain of the Andes and the Cordilleras, properly so called. Africa, too, has several basins without outlet, the principal one being that of the Lake Tsad, situated in the centre of the continent. Finally, even Australia, in spite of its comparatively small extent, has its lakes—Torrens, Gairdner, and others—which do not communicate with the sea.

As Bacon formerly remarked, the three groups of continents exhibit also a singular resemblance to one another in the pyramidal form of their terminal points in the direction of the Antarctic Ocean. These three southern peninsulas do not advance to an equal distance into the sea, as they reach respectively to 36, 44, and 56 degrees of south latitude, but they may be connected by an ideal circle, inclined 10 degrees to the South Pole. The distances between the extremities of the three continents are not very far from equal on the terrestrial periphery, as the tracts of ocean between the Cape of Good Hope and Cape Horn, Cape Horn and Tasmania, Tasmania and the South of Africa, are nearly in the ratio of the numbers 7, 8, and 9.

Each of these promontories, pushed forward, as they are, from the rest of the land, appears to have been partly demolished by the waves. Thus the extremity of South America presents the appearace of an immense ruin; the tortuous Straits of Magellan separate it from Tierra del Fuego, which is itself divided into numerous islets by a labyrinth of channels, and is guarded on the south, as by a couching lion, by the formidable headland of Cape Horn. At the southern point of Africa stands another "Cape of Storms," to which a feeling of confidence in the approaching discovery of India gave the name of the Cape of Good Hope. To the east of this promontory, which is connected with the main body of the continent by a system of plateaux and mountains, a great bank or ledge pushes out far into the sea; this bank is doubtless the remains of some vanished land, and the force of the marine currents still breaks over it. The Australian continent, also, has for its southern projection the steep shore of Van Diemen's Land; for, by its geographical position, this island evidently belongs to Australia; the error, therefore, of Cook, who looked upon Tasmania as nothing but a promontory of New Holland, was more apparent than real. There is another fact which completes

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the resemblance between the terminal points of the three continents of the antarctic hemisphere, namely, that each of the seas which extend to the east of these countries washes some island or considerable archipelago. On the east of Australia there is New Zealand, at the east of the South American continent we find the Falkland archipelago, east of Africa the large island of Madagascar.

These remarks of Bacon, since developed by Buffon, Forster, the companion of Cook, and in modern times by Steffens, Carl Ritter, Arnold Guyot, and other geographers, have given rise to the hypothesis that a terrible deluge, coming from the south-west, once rushed over the continents of the southern hemisphere, crumbling them up, dismembering them, and carrying their *débris* over the northern continents, thus forming the long slopes which incline towards the Arctic Ocean. The land in the north would thus be disproportionately augmented

Fig. 17.—Circle of Junction of the Continental Points.

at the expense of the south, of which nothing would be left, so to speak, but the skeleton. To this great inundation, which carved out afresh the great continental masses, Pallas, the Russian traveller, attributes the transport of the innumerable remains of mammoths which are found buried in the soil of the Siberian *tundras*. This hypothesis has been, as we know, since adopted by Adhemar and his disciples. In the opinion of these geologists, who recognise the great agents of terrestrial renovation in a series of periodical deluges proceeding alternately from the north and south every 10,500 years, the bones found in Siberia were brought there by the last deluge but one, which resulted from the breaking up of the ice at the south pole. According to one of these hypotheses, the last dissolution of the ice came from the south; according to the other, from the north. It is, therefore,

prudent to set aside these contradictory ideas which attribute to some cataclysm the peninsular form of the southern continents. Besides, at the present day, there is no longer any doubt that both the mammoth and rhinoceros were once natives of Siberia, the very country where their remains are now found.

Almost all the great peninsulas of the earth—as Greenland, Kamchatka, and Corea, including even those which would suggest a sudden change in the sea-level—extend in a southerly direction. Added to this, each of the three northern continents, in their southern articulations, seem to adopt as a type the three southern continents taken as a whole; thus, each puts out three peninsulas into the seas which bathe its southern shores. In Europe, Asia, and North America respectively, three groups of secondary peninsulas correspond to the three great promontories of the southern world.

In the Old World especially, these peninsular articulations are formed with a considerable degree of regularity, and, so to speak, of rhythm and measure; in the different continents they exhibit the most striking analogies. Arabia, in the proud and simple beauty of its outline, recalls to mind the elegant and yet majestic form of Spain; Hindustan, in the gentle undulations of its banks and the roundness of its bays, corresponds to Italy; India beyond the Ganges, by its numerous indentations and the enormous development of its coasts, seems the counterpart of Greece—that beautiful country, the outline of which has been so justly compared to that of a mulberry-leaf. In both continents, the peninsulas become more and more articulated, and more and more, as it were, endowed with vitality as we proceed from west to east. The Mediterranean peninsulas particularly present the remarkable phenomenon that the variety of outline is greater in proportion to their nearness to the rising sun. The numerous bays which hollow out the coast of Spain all along the Mediterranean shore are developed in regular arcs of a circle equal on the average to a quarter of its circumference. The Italian gulfs—those of Genoa, Naples, and Salerno—are spread out in perfect semicircles round the coast of the peninsula; whilst the gulfs of Greece form very deep indentations into the land, and, like the gulf of Lepanto, might be called Mediterraneans in miniature.

It must also be remarked that on the east of the somewhat severely designed coasts of the analogous peninsulas of Spain and Arabia the islands are but few and of small importance. Italy and India, on the contrary, the forms of which are richer, have each their large island, and with their southern extremities almost touch Sicily and Ceylon respectively. With regard to Greece and the Trans-gangetic peninsula, the seas which bathe their eastern coasts are dotted over with innumerable islands and islets, like a brood of young birds nestling under the wing of their mother. The two other eastern peninsulas, which are also thrown off by the great Asiatic continent, are each of them likewise accompanied by an archipelago.

The three southern peninsulas of North America do not exhibit the same regularity in their aspect as those of Europe and Asia. In conformity with the somewhat narrow and elongated form of the continent itself, two of these peninsulas—Florida and Lower California—seem attenuated in comparison with the analogous portions of the Old World. The other peninsular appendage, which, being placed in the very axis of the New World, is much more developed, is none other than the isthmus of Central America, now modified and distorted. In fact, a simple depression of the ground of about 100 feet is all that is needed in order that the Pacific and the Caribbean Sea should unite their waters between the

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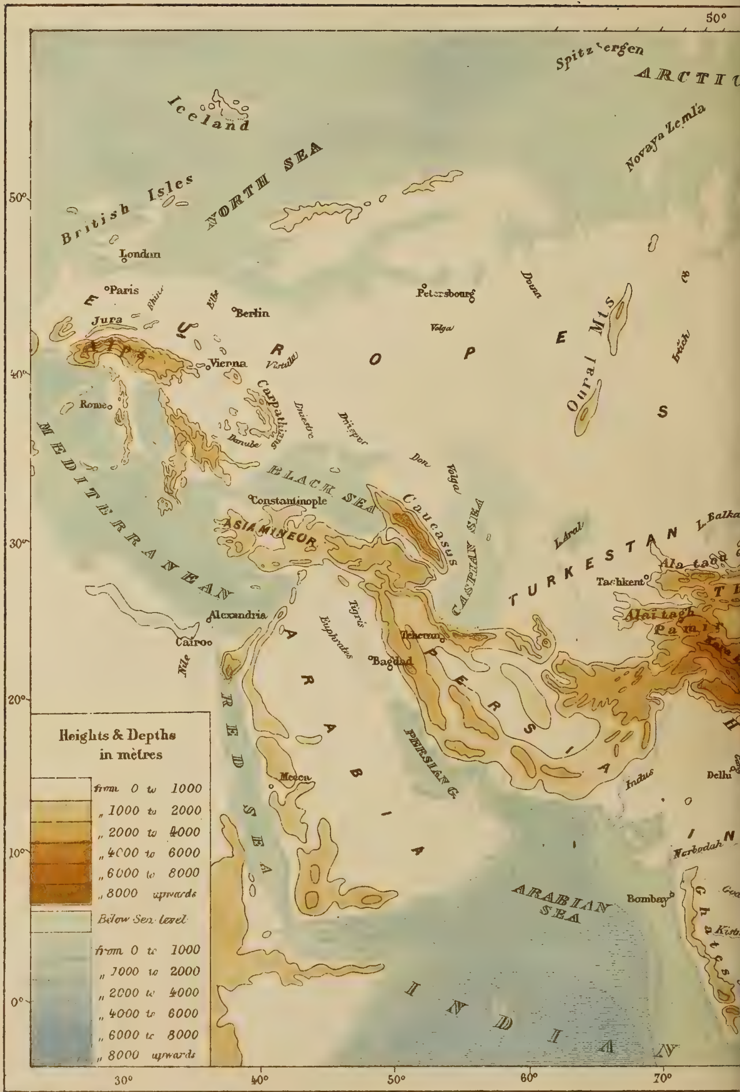
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BLACK SEA
Constantinople
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CASPIAN SEA
ASIA MINEUR
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Alexandria
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Tigris
Euphrates
Teheran
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two American continents; besides, it appears that, at a recent geological epoch, a channel, at least thirty-seven miles wide, connected the two seas across the plain which is now filled with a lava deposit, and is commanded on one side by the Sierra de Maria Enrico, and on the other by the Sierra Trinidad. A single feature of the earth's relief may at the same time fulfil several functions: thus, exactly at the antipodes of Central America, the Sunda Islands are also an isthmus between the two continents of Asia and New Holland.

There are numerous other analogies between the different parts of the world which we might also mention; but most of them may be referred to those we have named, or else they belong more to the province of geology properly so called.

CHAPTER X.

NUMEROUS INDENTATIONS OF THE NORTHERN CONTINENTS.—HEAVINESS OF FORM IN THE SOUTHERN CONTINENTS.—INEQUALITY OF SIZE IN THE CONTINENTS OF THE OLD WORLD.—EXTENT OF COAST-LINE IN INVERSE RATIO TO THE AREA OF LAND.—CONTRASTS BETWEEN THE OLD WORLD AND THE NEW.—THE TRANSVERSE POSITION OF THE AXES OF AMERICA AND THE OLD WORLD.—CONTRASTS OF CLIMATE IN THE VARIOUS CONTINENTS: NORTH AND SOUTH, EAST AND WEST.

THE contrast between the shapes of the various continental shores is one which is very easily verified. North America, Europe, and Asia, have a very considerable extent of coast-line in comparison with their bulk. They are penetrated for long distances by deep gulfs and inland seas, and their outline is rugged with promontories; it might be said that the organization of these continental masses bears some resemblance to an articulated body and its limbs. South America, Africa, and Australia seem, on the other hand, to enjoy but a rudimentary conformation; their contour is almost geometrically regular and simple, and their bays and gulfs are so slightly indented into the land that the regular line of the coast is scarcely altered; there is, too, an almost complete deficiency in promontories of a peninsular form. In the great scale of terrestrial organization, these continents present an inferior phase of life. Nevertheless, this heaviness of contour and deficiency of peninsulas are in great part compensated for by the more oceanic position of the southern continents, and the prevalence in them of a tropical climate. In fact, under the tropics, the air, being much warmer, is saturated by a larger quantity of moisture; and the atmospheric currents, being more rapid and regular, carry the sea-breezes across much wider areas. Thanks to the tropical rains, trade-winds, and hurricanes, the enormous masses of South America and even Africa are as much exposed to oceanic influences as other parts of the world which are more deeply indented by gulfs and bays. The three northern continents, on the contrary, the shores of which are so cut into and pierced in every direction, owe to their inland seas the ability (as regards a considerable portion of their surface) of imbibing those aqueous vapours without which they would be nothing but immense deserts.

The area of the continents is a fact no less important than their form, and the contrasts afforded in this respect are also not a little striking. Whilst the two halves of America are almost equal in extent, the four continents of the Old World differ much in the size of their respective areas. Asia, by herself, includes a larger surface of land than the two Americas together. Europe, pushed out into the ocean as a mere Asiatic peninsula, is four or five times smaller than the

enormous mass with which she is connected. In the south, the surface of Africa is three times as great as that of Europe; whilst Australia, compared with its northern neighbour, the area of which is six times larger, scarcely deserves more than the name of a great island. It must, however, be remarked that, by a very curious phenomenon of compensation, the two halves of each continental pair are arranged so as to balance on the terrestrial sphere. In the western pair, Africa, which is the preponderant portion, lies to the south, and the smaller Europe extends to the north. In the eastern pair, it is just the reverse: on the north is the great continent of Asia, and on the south the region of New Holland, which would correspond with Europe.

AREA OF CONTINENTS.

First Pair.	
North America	7,953,315 square miles.
South America	6,949,674 ,, ,,
Second Pair.	
Europe	3,822,320 ,, ,,
Africa	11,244,958 ,, ,,
Third Pair.	
Asia	16,771,879 ,, ,,
Australia	2,972,916 ,, ,,

The continents may also be compared by pointing out the respective distances of their ideal centres from the nearest point on the shore of the ocean.

CONTINENTAL RADII.

First Pair; mean radius, 975 *miles.*	
North America	1,087 miles.
South America	931 ,,
Second Pair; mean radius, 770 *miles.*	
Europe	478 ,,
Africa	1,118 ,,
Third Pair; mean radius, 1,017 *miles.*	
Asia	1,491 ,,
Australia	615 ,,

This great inequality in the size of the continents might furnish cause for surprise, were we not well aware that, according to the beautiful law propounded by Geoffroy Saint-Hilaire, no function can be unduly developed except at the expense of some other function. Europe is small, it is true; but what an opulence of coast-line does she enjoy! What profusion of gulfs and peninsulas diversify her outline; how many islands and islets there are in her seas! In Europe, land and water are arranged in alternate layers as if to form an immense electrical battery, where the acid, sheets of metal, and conducting wires are replaced by seas, land, and aerial currents. Europe is so variously articulated that she enjoys a more considerable extent of coast-line than either South America or Africa itself, both of which fill so much greater an area. Australia at first sight appears, from its solid form, to constitute a modification of the law according to which the smallest continental masses are the most highly organized. But Australia must

not be looked upon as an isolated body; we are bound to take into account the elongated isthmus of islands and islets which connects it with Indo-China. Along this former isthmus are scattered numerous archipelagos, presenting an almost incalculable development of coast-line, and consequently possessing all the advantages of climate, richness, and fertility which are afforded by a maritime position; there, too, more than in any other part of the world, the magnificence of terrestrial vitality is displayed in the splendour and variety of its productions.

The following tables, which give in miles the absolute and relative length of the sea-coast of each continent, are therefore necessarily incomplete. How shall we separate from Europe, England, Ireland, Sicily, and the isles of Greece—all of them countries which have played so important a part in the history of civilisation? How can we neglect, in the New World, the West India Islands, and the islands lying to the east of the continent of Asia—the Moluccas, the Sunda Archipelago, and Japan?

Extent of Sea-Coast.

First Pair.	
North America	29,969 miles.
South America	16,012 „
Second Pair.	
Europe	19,825 „
Africa	12,561 „
Third Pair.	
Asia	35,886 „
Australia	8,947 „

Proportion of Sea-Coast to Surface.

First Pair.	
North America	1 mile to 265 square miles.
South America	1 „ „ 434 „ „
Second Pair.	
Europe	1 „ „ 192 „ „
Africa	1 „ „ 895 „ „
Third Pair.	
Asia	1 „ „ 469 „ „
Australia	1 „ „ 332 „ „

By taking account of the principal islands—Great Britain, Ireland, Sardinia, Sicily, and several others—the total extent of the European coast-line may be estimated at 26,716 miles, which will give one mile for 143 square miles of surface.

In the two continents of the New World, the plateau and the plain show a surface nearly equal in extent, and in this respect present a harmony which does not exist in the Old World. All the western countries of North America, as well as a great part of its eastern regions, consist of plateaux, some level and others commanded by mountain chains. The plains which extend between these two systems of elevated ground, and embrace the fluviatile basins of British America and of the Mississippi and Missouri, are equal in surface to the higher regions along

the edges of the two coasts. In South America the plains are comparatively more extensive. Nevertheless, if to the chain of the Andes and their subsidiaries we add all the Columbian plateau, those of Peru and Bolivia, the groups of Famatina, Aconquiji, and Cordova, the *sierras* of the Guianas, the chains of the Brazilian coast and of Minas Geraës, the gigantic steppes of Patagonia between the ridges of the Andes and the Atlantic coast, we shall find that the balance is kept pretty equal between the high and the low lands of this part of the world. According to Humboldt, whose figures, however, should be carefully criticised with all the means afforded us by our increasingly exact acquaintance with the outline of the terrestrial relief, the mean elevation of North America is 747 feet, and that of South America would attain to 1,149 feet. But it is probable that more exact measurements would yield higher results, possibly a mean altitude of 1,300 feet for both continents.

The continents of the Old World do not afford an equal harmony in the general configuration of their elevation. Asia, taken as a whole, is a vast system of plateaux, extending from the headlands of Asia Minor to those of the Corea, and from the shores of Beluchistan to those of the province of Okhotzk. The central region of Asia, surrounded by the highest mountains in the world, is the most elevated district existing in any of the continents, and in some places attains the mean height of 9,000, 12,000, and 15,000 feet. The total area of the Asiatic plateaux is estimated by Humboldt at five-sevenths of this part of the world; Mesopotamia, the plains of the Ganges and of the Indus, China proper, and the Siberian *tundras* make up the other two-sevenths of the continent. As if to make up for this, Australia is comparatively very deficient in plateaux and mountain chains; of all the divisions of the earth this is the one which exhibits the least amount of prominence above the ocean level. The mean elevation can as yet be given but very hypothetically, as a great part of the regions of the interior is still unknown; but this continent must present about a third of the elevation of Asia—the latter being approximately estimated by Humboldt at 1,162 feet, which, however, may be as much as 500 feet too little.

Europe being situated, in the Old-World group, in a diagonal line as regards Australia, affords, like the latter continent, a great preponderance of plains and plateaux. Almost the whole of Eastern Europe is a level country, and this district —a great part of which is cultivated, although here and there covered with turf and heath—extends through Poland and Prussia as far as the frontiers of France and Belgium. Over this immense area, the level of the ground is so uniform that from Nijni-Novgorod to Cologne, a distance of 2,454 miles, there is not a single railway tunnel. In Western Europe, which, in a historical point of view, is the real Europe, the more elevated regions are, it is true, very numerous; but most of them amount to mere mountain chains, on each side of which extend considerable tracts of level country. The only plateaux of any notable importance in the general configuration of the continent are those of the Iberian peninsula, Suabia, and Turkey; all three, with a kind of rhythm, abut on mountain chains, the other faces of which command horizontal flats of alluvium. On the north of the Pyrenees and the Spanish plateau, lie the plains of the Garonne and Languedoc; on the south of the Bavarian plateau and the rampart of the Alps stretch the plains of Lombardy and Piedmont, forming a continuation of the level surface of the Adriatic Sea; finally, the low-lying lands of the Danube are separated from the plateau of Turkey by the Balkan chain, which extends in a line almost parallel to that of the Pyrenees.

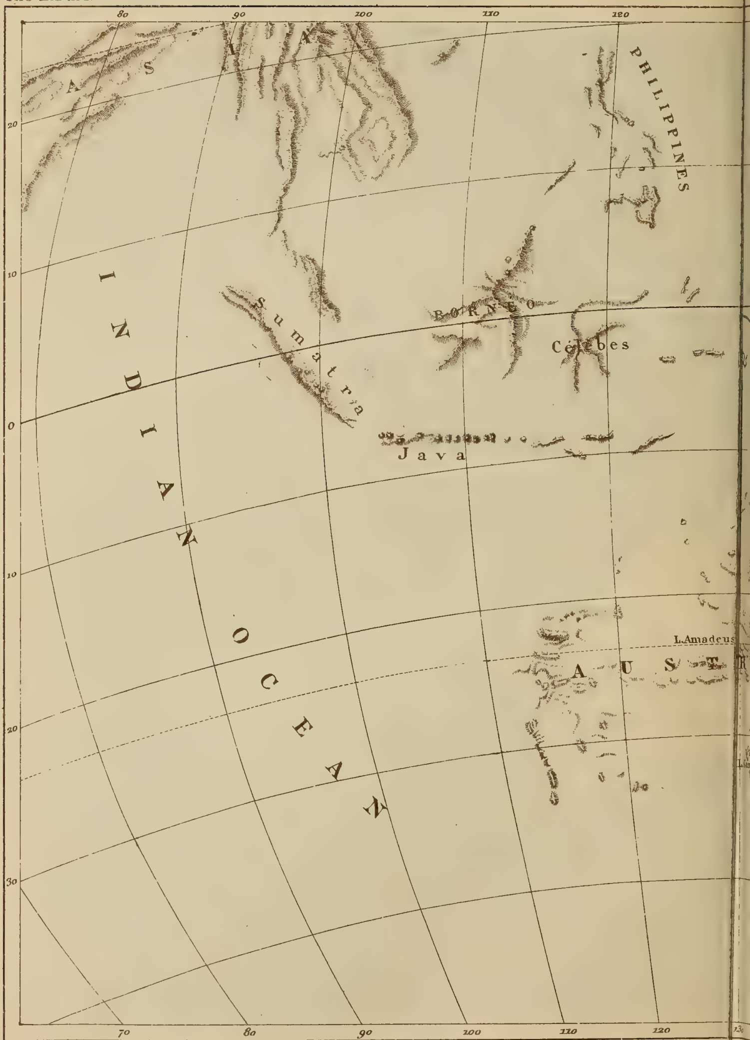
On account of the plateaux existing in Europe being so few, the mean elevation of this continent is not much more than half that of Asia; according to Humboldt it is about 672 feet. With regard to Africa, we need hardly say that it is impossible to fix the mean elevation with any certainty; but modern travellers who have penetrated into the interior of this division of the world have seen enough of it to warrant them in stating that Africa is very similar to Asia in respect to the elevation of the land. With the exception of Egypt, the plains of the Niger, some portions of the sea-coast, and districts of the Sahara, which were once covered by the sea, the continent is entirely composed of plateaux, most of which abut on lofty mountain chains. The *law of diagonals*, which is followed in the respective dimensions of the four continents of the Old World, is found also to hold good as regards their general configuration. Asia and Africa, the two continents in which the plateaux predominate, are placed diagonally to Europe and Australia, in which the plains are the most extensive.

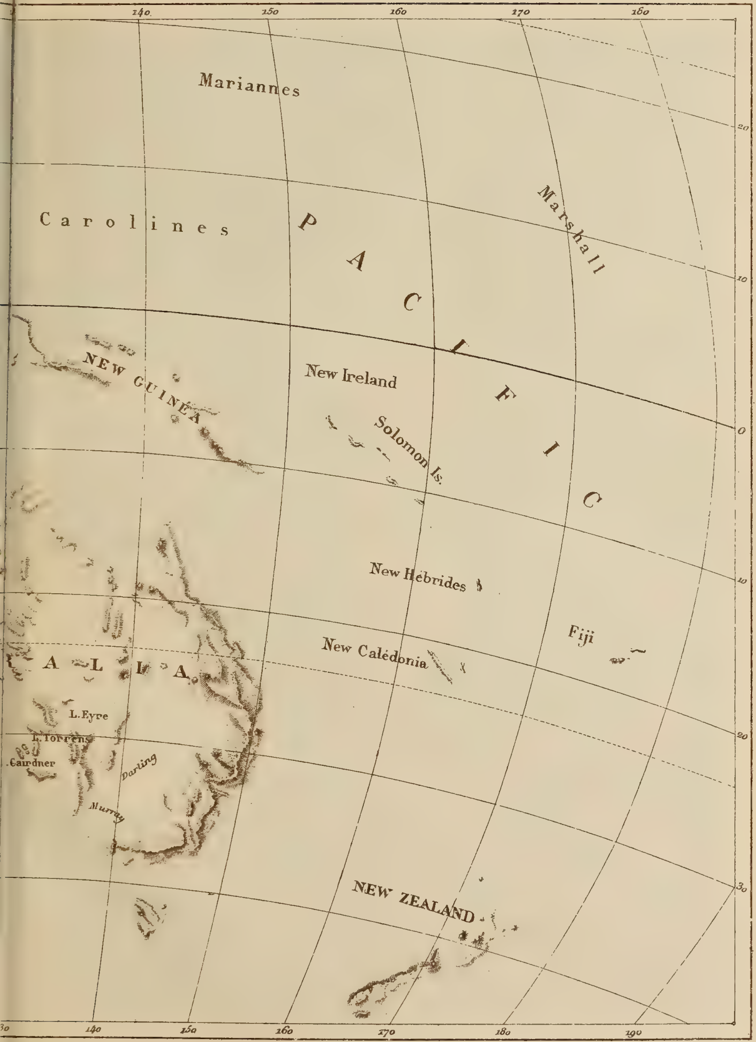
Another great contrast between the Old and New Worlds is one that is exhibited in the central portions of these groups. Between the two Americas stretches a sea of an almost circular shape, surrounded on all sides by a belt of islands and continental shore. The centre of the Old World, on the contrary, is occupied by the plains of Mesopotamia, and high ground towards which tend several seas in an oblique direction. The Persian Gulf, the Red Sea, the Mediterranean, the Euxine, and the Caspian surround this central spot of the Eastern continents, and approach the pentagonal mass obliquely at almost symmetrical intervals. Looking at the form and direction of these seas, it seems as if the region which they circumscribe had experienced a kind of wrench, as if it had been drawn into some vast eddy.

Another very remarkable phenomenon of equilibrium is exhibited in the fact that the highest mountains of each of the two halves of the world are situated in opposite hemispheres, but at an equal distance from the equator. Near one of the tropics rise the lofty Himalayas and the other great mountain groups of Asia; close to the other tropic stand the Bolivian and Chilian Andes.

There is another difference between the various divisions of the world to which we must call attention. In pursuance of the annular distribution of the continents round the great ocean, the western coasts of Europe and Africa correspond with the eastern coast of the New World, and not with the western, as analogy would seem to dictate. On the north, Scandinavia forms a counterpoise to Greenland. More to the south, the two shores which front each other across the North Atlantic bear a striking resemblance to each other in their numerous indentations, their deeply-penetrating gulfs, their peninsulas, and their islands, whilst between the coasts of Europe and those of California and British Columbia there is no symmetry whatever. With regard to Africa, several geographers, including Humboldt himself, have thought that this continent and South America had their corresponding coasts set in the same direction. But this is not the case; these two divisions of the world present the same mutual contrast as the two hands of a man. There is symmetry, but not equality. In fact, the highest plateaux and the loftiest mountains in Africa rise at the east side of this continent, whilst the chain of the Andes commands the western shores of South America. The most important African rivers—the Orange River, the Congo, the Niger, and even the Nile—empty their waters, either directly or indirectly, into the basin of the Atlantic, into which are also discharged the immense rivers of the Columbian continent—the La Plata, the Amazon, the Orinoco, and the Magdalena. In the

AUSTRALIA AND NEIGHB

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same way, the Saharan deserts which tend towards the Atlantic Ocean answer to the *llanos* of Venezuela and the *pampas* of La Plata; the latter being likewise inclined towards the same oceanic basin. Finally, the two isthmuses of Suez and Panama, each at the angle of their respective continents, occupy a corresponding though opposite position. Similarly, Cape Verd must be considered as the correspondent point to the Brazilian promontory of St. Roch, and the Gulf of Guinea is represented on the other side of the ocean by the wide semicircle of coast which opens out on the south of Brazil. Even in the bed of the sea the symmetry still prevails, since an upheaval of 4,500 yards would have the effect of calling forth in the midst of the Atlantic a long strip of land separated from Europe and the New World by two parallel channels.

In each of the two groups of continents, the steep and gentle inclines are distributed respectively in contrary directions. In Europe, Africa, and Asia, the most elongated incline of the land tends in a northerly and westerly direction towards the Atlantic Ocean and the Frozen Sea. In the New World the more gradual slopes of the continent likewise descend towards the Atlantic coast, that is, in an eastward direction. We thus have a contrast which is also a harmony; it is as if the faces of the two worlds were turned one to the other, thus rendering more easy of access their coasts, their plains, their rivers, and all the regions suitable for the abode of man.

Another contrast, which is perhaps the most important of all in the history of mankind, is that exhibited by the transverse position of the two groups of continents in reference to each other. The countries of the Old World, which show the richest luxuriance and the most exuberant vitality, lie between the Straits of Gibraltar and the Archipelago of Japan, and extend from west to east in a line parallel to the equator; the New World, on the other hand, stretches from north to south, in the direction of the meridian. Thus, the double continent is set right athwart the course followed by the winds and the currents, and across the path taken by the human race in making its way from the other group of countries; it, therefore, receives and develops the germs of life, the elaboration of which had commenced on the other side of the sea. This transverse position of America in respect to the Old World is one of the principal features of the planetary relief, and one also which exercises a decisive influence on the future of the whole human race.

Finally, it must not be forgotten that the principal contrasts of the continental masses proceed naturally from all the modifications produced by the difference of longitude and latitude. These contrasts are those of climate, and their real cause is to be found in the form of the earth and its movements round the sun.

Thus, the astronomical contrast between the north and the south divides distinctly the different parts of the world into two separate groups. Almost the whole extent of the three northern continents belongs to the temperate zone, and it is only their most advanced peninsulas which are pushed forward—on one side into the frigid, and on the other into the torrid, zone. With regard to the three southern continents, they present their chief development between the tropics, or in the south temperate zone. They receive the greatest amount of annual heat, and consequently become the theatre of the most remarkable phenomena of planetary vitality. There the cross-action of the winds and rains between the two hemispheres takes place, and hurricanes take their rise; there, immense deserts extend over vast areas; there, too, vegetation manifests all its productive energy, and the terrestrial Fauna attains its greatest force and its highest beauty.

The contrast between the east and the west is also of the highest importance in each group of continents; for all the train of climatic phenomena which accompanies the sun in its apparent course round the earth does not uniformly follow the latitude in a parallel line to the equator. In consequence of the unequal division of land and sea, there is a modification in the direction of the currents and winds, and also a transposition of the climates themselves—sometimes towards the north, and sometimes towards the south; the most distinct contrariety in this respect is thus produced, in some cases, between the western side of one continent and the eastern side of the continent opposite to it. It is principally between the Old and New Worlds that this contrast is most striking; at equal latitudes, the western shores of Europe, and those which face them on the other side of the Atlantic, have very different climates—a fact which is caused by the changes produced by marine currents, the winds, and all the other atmospheric phenomena.

CHAPTER XI.

HARMONY OF SHAPE IN OCEANS.—THE TWO BASINS OF THE PACIFIC.—THE TWO BASINS OF THE ATLANTIC.—THE ARCTIC FROZEN OCEAN AND THE ANTARCTIC CONTINENT.—CONTRASTS, AN ESSENTIAL CONDITION OF PLANETARY VITALITY.

THE harmony of the continental forms is fully paralleled by that of the oceanic configuration. The Southern Ocean alone—that mighty breadth of waters, in comparison with which all the other oceans seem but mere arms of the sea—extends over nearly an entire hemisphere of our planet. Notwithstanding its enormous dimensions, it none the less exhibits a most harmonious *ensemble*, caused partly by the amphitheatre of shore spread all round the Pacific, from Van Diemen's Land to Tierra del Fuego; partly also by the marvellous belt of the Polynesian archipelago. These numerous and lovely islands, which Ritter calls the "Milky Way of the ocean," are dotted obliquely over the whole breadth of the south seas, from the Philippines to Easter Island, dividing the immense basin of the Pacific into two sheets of water, distinct from each other both by their winds, the course of their currents, and the undulations of their waves. Thus, the great hemisphere of waters constitutes a kind of oceanic pair, in accordance with the same law which distributed the land in three continental pairs.

The tortuous valley of the Atlantic, which separates the Old World from the New, is also decisively divided into two basins, differing in the shape of their outline, their climates, winds, and currents. An ideal line, traced from the Cape Verd Islands to the nearest of the Antilles, marks the limit of separation between the two halves of the great oceanic valley. On one side, the South Atlantic spreads out in a vast semicircle between the scarcely undulated shores of the more massively formed continents; on the other, the North Atlantic gradually contracts towards the polar regions, throwing out, both to right and left, gulfs, channels, and inland seas. On the east, the Mediterranean, the British and the Irish Channels, the North Sea, and the Baltic; on the west, the Caribbean Sea, the Gulf of Mexico, the island-studded estuary of the St. Lawrence, Baffin's Bay, and Hudson's Channel and Bay—all these appear to correspond on either side of the ocean, and, by the resemblance of their outlines, add to the harmony of the continents themselves. Thus, the general form of the two Atlantic basins recalls to mind the two continental pairs, the shores of which they bathe. The northern basin, bordered as it is by variously articulated lands, is, from this very cause, the richest of the two oceans in indentations of every kind, and is also that which was destined by nature to become the high-road of the commerce of nations.

The Indian Ocean, shut up, as it is, in the immense hollow formed by the coasts

of Africa, Arabia, the Gangetic peninsula, the Sunda Isles, and Australia, cannot exhibit the same characteristic of duality as the two other oceans—the Southern Ocean and the Atlantic. If, however, we take into account the ancient geological conditions of Asia, we may, perhaps, be warranted in looking upon the Caspian, the Sea of Aral, and the other lakes of Western Asia, as the remains of the former ocean which, in the northern hemisphere, formed the equipoise to the Indian seas. There would then have been three double oceans, just as there are three continental pairs. Added to this it is probable that the northern and southern polar regions likewise afford an instance of an equilibrium existing between land and water. We are at present but very imperfectly acquainted with the regions either of the north or south poles; but the explorations of navigators and the investigations of meteorologists more and more tend to confirm the old hypothesis, which supposed that open sea extended round the arctic pole, and that the circle of the south pole was occupied by a covering of dry land. If this be really the case, the harmony of the continental masses, and the sheets of water which are interspersed among them over the surface of the planet, is admirably completed by the contrast between the two poles of land and water which occupy the two extremities.

The general similarities and the great contrasts which we have now pointed out constitute but a small number of the features of this kind which the surface of the globe presents, and it would be an easy thing thus to follow out our parallels from sea to sea, from river to river, and from mountain to mountain. But the purely external symmetry presented by the continental configurations is a trifling matter compared with the profound harmony resulting from the alternation of winds, currents, climate, and all the geological phenomena. It is not in the various portions of the globe but in their working action that we must seek for the real beauty of the earth. Planetary vitality is composed of perpetual contrasts in a perpetual harmony, and these very contrasts are incessantly being modified. Continents, seas, and atmosphere—and, in a more special way, every mountain, every peninsula, every river, every marine current, every wind that blows—may be considered as the organs of the globe on which we live; it is therefore by watching these organs at work, and by studying deeply and thoroughly their action and reaction, that we can best arrive at an acquaintance with the physiology of the planetary body.

Physical geography is nothing else but the study of all these terrestrial harmonies. An inquiry into the superior harmonies which emanate from the relations of mankind to the planet which is the scene of human life must be left to history, the task of which is to describe them.

CHAPTER XII.

GENERAL ASPECT OF PLAINS.—ALLUVIAL PLAINS.—CULTIVATED PLAINS.—UNIFORMITY IN UNCULTIVATED PLAINS.—VARIETIES IN APPEARANCE PRODUCED BY CLIMATES AND DIFFERENT PHYSICAL CONDITIONS.

THE portions of the terrestrial surface on which the vitality of the globe shows itself with the least intensity and variety are those countries which present the slightest diversities of level. In these regions, the flatness or slight declivity of the surface of the earth prevents the waters from flowing rapidly; the country exhibits the same amount of vegetation, or the same sterility, over vast extents, and its general aspect is often most monotonous. Nevertheless, in spite of the uniformity of a flat district, the phenomena of nature are all the more easily observed there, because they are developed in a more simple and regular manner.

Nearly half of the continental regions is composed of low and comparatively level lands, the even or gently inclined surface of which still testifies to the action of the waters of the ocean or of the inland seas by which it was formerly covered. These are former sea-beds, which have emerged from the deep; and, from the uniformity of their appearance—often much resembling a tract of ocean—contrast sharply with the high lands or mountains surrounding them. Some of these plains, which are watered by streams and rivers, have been greatly modified by the courses which the latter have taken; and, by means of the fertile alluvium that has been brought to them, and the moisture which penetrates them, have spontaneously given birth to immense forests. They then lose their resemblance to the surface of the sea, except when looked at from the top of some lofty bluff, around which the thick trees seem to crowd like billows. At length, when man comes to take possession of the plains, to erect his towns and to cultivate the soil, he introduces a great variety into these uniform tracts, and never ceases to modify their primitive aspect. These low-lying regions which, by reason of the flatness of the ground, are destined to be the scene of but slight activity in the planetary life, have become the principal seat of mankind, and it is there that civilisation makes its most remarkable progress.

The plains which best retain their appearance of times gone by are those which, owing either to the want of rain, or the almost complete absence of slope either in one direction or another, are watered by only a small number of streams, or sometimes, throughout vast tracts of country, are utterly without them. For this reason, in many parts of the globe, a plain and a desert are almost synonymous. Setting aside the low lands which have been brought under cultivation, the plateaux and the intervening mountain-chains, we find that there is a coincidence between most of the large level plains and the continental deserts. Thus the western and eastern regions of the Sahara, the Nefud of Arabia, the steppes of the Caspian, the Aral,

the Balkash, and the *tundras* of Siberia, are at the same time the most extensive plains and the most widely-spreading deserts on the face of the globe. The general axis of the principal plains in the Old World, as well as that of the deserts, mountains, and continents themselves, is set in a direction from south-west to north-east; whilst in the New World the axis of the low-lying lands tends from north to south in a parallel line to the chains of the Rocky Mountains and the Andes.

All lands which are bare plains, destitute of large trees, resemble one another on account of their uniformity. On the surface of these plains, as on the sea, it is only necessary to scan the horizon round in order to perceive clear proofs of the rotundity of the globe. Although the sight reaches without difficulty over the bare ground or its green carpet of plants, yet the bases of hills and the trunks of trees which appear at the limits of the plain are hidden by the convexity of the earth. At first we only perceive the summits of the hills and the branches of the trees; then, in proportion as we draw nearer, the lower declivities and the trunks of the trees begin to make their appearance, in the same way as, in the open sea, the hull of a ship is not seen until long after the sails and masts have come into view. Lastly, as on the ocean, the variable aspect of the sky, to which, in hilly countries, we are in the habit of paying only a secondary attention, here regains all its importance, and becomes the principal feature in the landscape. The uniform and motionless surface of the plain slopes down towards the horizon, like the back of a gigantic shield, and its whole extent offers no object which can arrest the attention; but above, on all sides, stretches the enormous dome of the atmosphere, with its fitful play of light and shade, the successive gradation of its colours, from deep blue to fiery purple—its clouds, which, chasing one another across the sky, first disperse and then cluster together, drawing themselves out into long transparent lines, or accumulating in masses of a sombre gray. Occasionally, when the air which hangs over the plain is unequally heated by the rays of the sun, distant objects assume a distorted shape, seem nearer than they really are, or, perhaps, inverted, producing that fantastic illusion called a mirage, which was formerly believed to be the work of mocking genii.

Although all the bare plains on the various continents resemble one another in the curvature of the ground, the circularity of the horizon, and the play of the atmosphere, yet their aspects sometimes vary much in different countries, according to the geological nature of the soil, the mean temperature, the changes of the seasons, the direction of the winds, the quantity of rainfall, and all the other physical conditions of the region generally. Thus, a clayey plain is hard and compact, like the ground of a threshing-floor which has constantly been beaten with the flail; another, the rocks of which are of a calcareous nature, is intersected here and there by ravines with perpendicular sides; another is sandy, and, under the influence of the wind, is rippled with waves like the surface of the sea. Some, but these are rare, present vast extents completely destitute of vegetation; others offer, here and there, a solitary green plant; but every one of them is a plant of the same species, and one may travel whole days in these deserts without seeing any other representatives of the vegetable world. The greater number of plains have, it is true, a Flora, composed of a tolerably large number of species; but two or three plants which are commoner than the others, appearing uniformly on hundreds and thousands of acres, have appropriated to themselves the whole district, and thus give it a special character. Lastly, some solitudes are temporarily, during the rainy season, or even during the whole year, magnificent and verdant prairies enamelled with flowers. These are the tracts which man can most easily turn to account by breaking them up with the ploughshare.

CHAPTER XIII.

THE FRENCH LANDES.—THE BRANDES AND THE ALIOS.—THE CAMPINE.—THE HEATHS OF HOLLAND AND NORTHERN GERMANY.—THE PUSZTA OF HUNGARY. —THE GRASSY STEPPES OF RUSSIA.—THE SALT STEPPES OF THE CASPIAN AND THE ARAL.—THE TUNDRAS.

THANKS to the rains blown up by the sea-breezes, the comparatively small deserts of Western Europe do not assume the formidable character of the Sahara, or the Nefud of Arabia. Those best known are the *landes* of Gascony.

The old tracts of French *landes* embrace not only the department which takes its name from them, but also include half of La Gironde, as well as the extreme corner of Lot-et-Garonne, extending over nearly 2,500,000 acres. This region, which was once covered by the waters of the Atlantic, is a plateau averaging 160 to 190 feet in height, and sinking in a gentle decline on the north-east towards the Gironde and the Garonne, on the west towards the lakes on the seashore, and on the south towards the river Adour. The uniformity of the great plateau of the *landes* is so great that, for a distance of twenty-eight miles between Lamothe and Labouheyre, the railroad from Bordeaux to Bayonne is perfectly rectilinear; one might call it a "visible meridian."

For some years past the labour of man has done much in turning to account this vast domain, once so neglected. Private individuals and communities have, with equal ardour, sought to enrich themselves by replacing the heath with pines and other trees; and there can be no doubt that in the near future the whole extent of the *landes* will be covered with forests and cultivated grounds. There are now but few places where we can still see what the whole plateau once was, stretching from the edge of the vineyards of Bordeaux to the country at the foot of the first Pyrenean hills.

In these uninhabited tracts the landscape is certainly deficient in variety, but it always possesses a certain grandeur and a singular charm for those who love nature in all her freedom. All round, within the limited circle which is surrounded by the level line of the horizon, nothing is to be seen but a thick underwood of *brandes* and various other kinds of heath, springing up to the height of a yard or two above the ground. During their flowering time these plants mingle a light shade of pink with their delicate green, but they appear everywhere bristling with a number of heath-branches, leafless, and black as if charred in a fire. In other spots tall ferns have taken possession of the ground, filling the air with their penetrating odour. Farther on, we come upon large patches of furze and broom, which flower together in the spring and cover the plain with an immense veil of

gold. Mosses, grasses, and briars grow together along the edges of the paths; water-lilies and other aquatic plants repose quietly on the surface of the muddy pools; tufts of rushes and sedge spring up in the spongy earth around the water. And this is all. Perhaps, on the extreme horizon, a bluish line, pointing out the edge of a pine forest, may be faintly visible.

Over a vast extent of the *landes,* the surface soil is composed of a white and almost unmixed sand; but in general it is very much mingled with vegetable

Fig. 18.—The "Landes" of Gascony.

remains, which give it a gray or blackish colour, like charcoal ashes. Below this upper layer extends a stratum of agglutinated sand, generally of a rusty colour, and bearing a great similarity in appearance to ferruginous sandstone; the hardened dust known in the *landes* of Médoc under the denomination of "alios" owes its colour and its firmness to the continual infiltration of rain-water, which carries down into the ground various organic substances in a state of solution, and blends them intimately with the arenaceous particles. In a general way *alios,* notwithstanding its ferruginous appearance, contains the oxide of iron only in an almost

imperceptible proportion. When it is thrown into the fire it is noticed to carbonize slowly, and is then reduced to ashes; yet, in certain localities, especially in marshy districts where the argillaceous iron is naturally formed, the subjacent layer is gradually changed into an actual mineral. Generally, the bed of *alios*, which is hardest where it is least thick, is completely impervious to water, like a stratum of rock. Rain-water, being thus checked by the continuous layer of *alios*, must necessarily remain in the upper soil, and during the wet season the surface of the *landes* would be changed into one great marsh if care were not taken to cut trenches or drains, which receive the overflow of the scattered pools, and carry them either to the different rivulets or to the lakes on the sea-shore. In order to cross more easily the sheets of water which sometimes extend farther than the eye can reach between the patches of heath, the shepherds of the *landes* have adopted the custom of walking and watching over their flocks on stilts more than a yard high. In this respect the Lanusquets, or Landescots, were till recently supposed to be without parallel in the world; but it now appears that a similar method of locomotion is also practised in some of the swampy islands of the Lower Elbe.

Nearly all the regions of Western Europe which were in early ages covered by the sea, and have since retained the uniformity of surface of the former sea-beds, have long since come under cultivation; such are, for instance, the low ground of the ancient Gulf of Poitou, the filled-up estuary of Flanders, the largest part of Holland, and German and Danish Friesland. But, farther inland, there are here and there tracts of *landes* like those of Bordeaux. In France one may mention those of Sologne and Brenne, which were formerly a vast forest of about 1,234,000 acres in extent, and are now being transformed anew by patches of pines, drainage canals, and other improvements. In Belgium the sandy *landes* of the Campine, which, since the establishment of the Germans and Batavi in the neighbouring countries have always been a flat surface of heaths dotted over with pools, extended in 1849 over a surface of 345,000 acres; but the brave Belgian husbandmen who laid siege to these *landes* continue to reduce their dimensions at the rate of 3,950 acres a year.

In Holland and the north of Germany the belt of heaths assumes its greatest width, and extends over a much more considerable surface than that of the *landes* of Gascony. In Holland alone an extent of about 4,196,875 acres, more than half the territory, consists of a sandy soil, which was once nothing but a vast solitude, the uncultivated parts of which still contrast most strikingly with the rich *polders* of the coast. A great part of this sandy region, which is elevated, upon an average, 48 feet above the sea, is covered with spongy peat-mosses, which will readily burn after having previously been dried by means of drainage canals, and cut into pieces of a proper size. One fine day in the summer time the peasants set light to these masses of dry turf, and soon the conflagration spreads over wide extents, and thousands of acres are burning at the same time. When the north wind passes over these immense fires it carries with it smoking particles of the smouldering turf hundreds of leagues away from Holland, and sometimes even to the centre of France, Switzerland, Bavaria, and Austria. This is the origin of those dry fogs, or northern fogs, which give a yellowish tint to the atmosphere, and sometimes half hide the face of the sun. However, when the wind is favourable, a comparatively slack fire transmits its smoke to very great distances; thus, in 1865, at the time of the fire in a part of the city of Limoges, the cloud of smoke, which stretched away in long eddies towards the west, was perfectly visible as far as Marennes, a distance of about 125 miles in a straight line.

The *landes* of the north of Europe enjoy a colder climate than those of Gascony, therefore their vegetation is less developed and not so diversified; but it seems that in both belts of heath the composition of the soil is nearly the same. In Germany and in Jutland, as well as in France, the yellow colour of the sand is due to the gradual infiltration of the juices of the plants, which are loaded with tannin; and the ferruginous-looking *tufa*, which is found at a certain depth in the substratum, through which the roots of trees cannot penetrate, is no doubt nothing else than a bed of hardened sand of the same nature as the *alios* of the French *landes*. In Jutland, where this bed is on an average from two to four inches in depth, they give it the name of *jern-al*, or iron-sand. In England, Scotland, and Ireland a

Fig. 19.—Extent of the Heath-smoke in 1857.

thin bed of "iron-pan," of the same appearance, is found under the large barren heath-covered moors.

Very different, indeed, in their vegetation are the large grassy plains of Hungary and Central Russia; they are, in fact, immense prairies, not less uniform than the *landes*, but presenting a much more lovely and pleasing aspect, especially in the season of flowers. The *Magyar Puszta*, so celebrated by Petœfi, was formerly a lake of more than 310 miles in circumference, bounded on one side by the large bend of the Danube from Pesth to Belgrade, and on the other by the semicircle of the Carpathians and the western mountains of Transylvania. The soil, which is nourished by the fertile alluvium that the Tisza, the Maros, and other rivers bring down from the surrounding mountains, is very fertile, and in the cultivated districts yields abundant crops. Vast extents, which are left as natural meadows, look like perfect seas of waving grasses, over which roam in unrestrained freedom herds of half-wild oxen and those uncouth horses which are ridden by the rude *Czikos* troopers. The beauty of these green and flowering plains, dotted over with low,

mud-built houses, often hidden almost to the roofs in the tall herbage, is heightened by the contrast afforded by the wide semicircle of blue mountains forming the distant horizon.

The grassy steppes of Central Russia do not possess, like the Hungarian *puszta*, this beautiful framework of lofty mountains, but they offer a charm no less peculiar in the beauty of their flowers and the gracefulness of the ears of corn gently waving in the breeze. The vast region of the *Tchornosjom* (black-earth), thus named on account of the colour of its soil, is still in great part a sea of grasses, varied only here and there by villages, cultivated fields, and rivers flowing slowly between steep banks. The Tchornosjom, which extends over the valleys of the Don, the Dnieper, and the Volga, comprehends an area of more than 197,500,000 acres, nearly twice the size of France, and throughout this immense district the vegetable soil is of a depth varying from 3 to 15, and sometimes even reaching to 30 and 60 feet. Thus the geological nature of the soil proves that this plain is not of oceanic origin; marine *débris* is not found in any part of it, nor any of those irregular boulders brought down from the mountain glaciers of Scandinavia. The "black lands" were formerly an irregularly shaped continent, surrounded on all sides by water. Though they are incessantly fertilized by the remains of decayed turf, yet they seem unable to nourish the roots of trees; forests, therefore, are entirely wanting in these regions; thanks also to the natural drainage, there are no stagnant swamps. These lands, prepared for culture by a grassy vegetation for many thousands of centuries, are among the best in the world for the production of cereals, and, sooner or later, they will become one vast field of corn.

To the south of the Tchornosjom there are, here and there, some oases of the same nature which are equally remarable for the richness of their vegetation; but the greater part of the steppes are former sea-beds, which have emerged at a recent epoch, and exhibit no traces of verdure except in the spring. The heat of summer soon scorches up the grass, and the flocks which graze on these vast plains are obliged to take refuge by the banks of the rivers in order to obtain their food. The only oases of the steppes of the Don and the Dnieper are those districts in which the inhabitants have been able to renew and purify the soil by the use of spring water. Some villages, which were founded in the last century by German colonists, are perfect little nests of verdure, the beauty of which contrasts most strikingly with the formidable aspect of the surrounding solitudes.

Nearly all the countries of Russia and Tartary, which are situated below the level of the sea in the great Caspian depression, are steppes of a still more arid and desolate character than those even of Southern Russia. They are interminable tracts of loose sand, interspersed with banks of hard clay, like a threshing-floor beaten solid by the flail, and beds of rock here and there intersected by clefts in which a little vegetable soil sometimes accumulates. These steppes of sand or clay comprehend the principal part of the western basin of the Caspian; the rocky steppes extend to the east towards Tartary; lastly, the salt plains, which by their efflorescence bear witness to the fact of the former extension of the sea, occupy a considerable tract between the course of the Volga and that of the Yâk. There, too, is situated the desert of Narin, the clayey and barren surface of which is scattered over with sandy plateaux covered with verdure, and crossed from north to south by a chain of downs sheltering the pastures which lie half-hidden in the hollows. With the exception of these scanty green patches, which are frequented by some few wandering tribes, nearly the whole of the Caspian depression is the very picture of aridity. No natural meadows reach the eye, like those in the steppes of the

Dnieper, the Don, and the Irtysh; and the pastures occupy only a very limited breadth at some considerable distance to the north of the present sea-shore. When the locusts settle down there, which is frequently the case, not a blade of grass is left, and the very reeds in the marshes are eaten down to the level of the water.

It is well known what a forbidding aspect the surface of the steppes presents in the middle of winter, when all is hidden under the snow, and the freezing wind stirs up this silvery sea into waves and eddies. But even in the most joyous season of the year the immense extent of white sand and reddish clay, varied here and there with scanty shrubs of wormwood and euphorbia, with their sombre-coloured leaves, likewise presents a most dreary appearance. The vast tracts of

Fig. 20.—The "Black Lands," of Russia.

ground, which are crossed by travellers in cars drawn by horses at full gallop, appear like a fiery-coloured sheet striped with long gray lines. Here and there ravines, hollowed in the soil by the torrents of rainstorms, have to be crossed with great labour; then some marsh, with its thick whitish waters seen in glimpses through a forest of reeds, has to be avoided. In the distance a border of blood-red saltwort betrays the presence of a salt pool, and quite in the extreme horizon, heavy hanging clouds, in long rows, one above the other, point out the vicinity of the sea-shore. The soil reflects an intolerable amount of heat. At the same time the breeze, drawn as by a centre of attraction to the burning surface of the steppes, raises before it columns of dust; at the side of the car the *débris* of withered plants may be seen strangely bounding along by thousands and by millions; these *racers of the steppes,* which are rolled into balls by the wind, seem

to be having a contest of speed, and, keeping close to the earth, pursue each other furiously, sometimes making leaps of several yards. One might almost fancy that they were human beings hurried along in some demoniacal race. At the end of each stage the traveller stops an instant before a miserable cabin, half buried in the sand. He catches a glimpse of a human face with haggard eyes and disordered hair, and then off he goes again like a dart, to plunge anew into the desert. It is seldom that he can distinguish in the distance the *kibitkas* of the Calmucks or the Kirghizes, or the tombs formerly raised over the bones of warriors. Frequently hundreds of miles are accomplished without seeing any other trace of man having passed over the same route, except the ruts left by the wheels in the hardened clay. In these solitudes trees are almost completely unknown, and the few that are found there are looked upon with a kind of adoration, as if they were the miraculous gifts of some divinity. Between the Sea of Aral and the confluence of the Tchoni and the Yatchi, that is to say, a distance of 310 miles in a straight line, only one tree is to be found, and this is a species of poplar, with drooping boughs, the roots of which creep far into the arid soil. The Kirghizes have such a veneration for this solitary tree that they often go several miles out of their way in order to pay it a visit, and each time they hang an article of their clothing upon its branches. From this custom the name of *sinderishagatch*, or "rag-tree," has been given to the desert poplar.

The plains of Southern Siberia, which extend eastward as far as the Altaï Mountains and the Lake of Dsaï-Sang, present a very diversified aspect compared with the steppes of the Caspian, and even with the *landes* of France and the heaths of Germany. These plains are intersected in various directions by chains of rounded hills and by woods of coniferous trees, which here and there bound the horizon and give a little life to the whole landscape. Besides the meadow grasses, hundreds of plants and shrubs also embellish the surface of the ground. In the spring rosaceous plants, thorny plum-trees, cytisi, tulips, and other plants, with white, pink, yellow, and variegated flowers, glitter on the greensward of the undulating valleys of the steppe.

In the north of Russia and Siberia the long plains which descend in an imperceptible slope towards the Arctic Ocean are not less solitary than the Caspian steppes, and have an equally formidable aspect. During a great part of the year the circular space bounded by the horizon presents nothing but an immense winding-sheet of snow rippled by the wind. When this bed of snow melts under the summer sun, the lowest districts in the plain, or *tundra*, appear dotted over here and there with patches of *Sphagnum* and various other green plants, which grow and swell almost like sponges by means of the half-hidden pools of water. Nearly the whole extent of the soil is covered with reindeer moss and other whitish lichens; and one might readily fancy that the interminable carpet of winter snow was still spread before one's eyes. In these regions, however, the earth is always frozen to a great depth, in spite of the rudimentary vegetables which grow on its surface and the lagoons of water which sparkle during several months in the marshy depressions of the soil.

CHAPTER XIV.

SEMICIRCLE OF DESERTS PARALLEL TO THE SEMICIRCLES OF LANDES AND STEPPES.—THE SAHARA.—SANDS, ROCKS, OASES.—THE DESERTS OF ARABIA.—THE NEFUD.—DESERTS OF IRAN AND THE INDUS.—THE DESERT OF GOBI.

AT a great distance to the south of this zone of *landes,* prairies, steppes, and *tundras,* which extends in an irregular semicircle from France to Siberia, there is another zone of plains, deserts, and plateaux which curves round in a parallel direction to the former, and exhibits a still more formidable and monotonous aspect. This zone, which is crossed by an imaginary line called by John Reynaud the "equator of contraction," comprehends the great Sahara of Africa and the deserts of Arabia, Persia, Gobi, and Chinese Mongolia. This zone is in a great measure destitute of water and vegetation, and, on the whole, is much less accessible to man than the northern solitudes. Not only is it more intensely heated by the solar rays, but it also enjoys a much less amount of moisture on account of the chains of mountains which, at several points, impede the passage of the rain-clouds, and especially on account of the position it occupies as extending diagonally across the most massive portion of the two largest continents, Africa and Asia.

The most important group of deserts in the world is that of the Sahara, which extends across the African continent from the shores of the Atlantic to the valley of the Nile. This immense area is more than 3,100 miles from east to west, and is, on an average, more than 600 miles in breadth; it is, in fact, equal in size to two-thirds of Europe. This is the part of the earth in which the heat is most intense; although it is to the north of the equator, yet, as regards most of the world, it is the real *south,* and the principal focus of attraction for the atmospheric currents. In this region there is only one season, viz. summer, burning and merciless. It is but rarely that rain comes to refresh these regions, on which the solar rays dart vertically down.

The mean altitude of the Sahara is estimated at 2,000 feet; but the level of the soil varies singularly in the different districts. To the south of Algeria, the surface of the Shott Mel-R'ir, the remains of an ancient sea which communicated with the Mediterranean, is at the present time more than 165 feet below the Gulf of Cabes; whilst to the south and east the ground rises into plateaux and mountains of sandstone or granite to a height varying from 3,300 to 6,600 feet. In the centre of the Sahara stands the Jebel-Hoggar, the sides of which are covered with snow during three months in the year; from December to March its picturesque defiles are traversed by streams which flow some distance and lose themselves beneath the surrounding plains. This group of lofty mountains is the great landmark which

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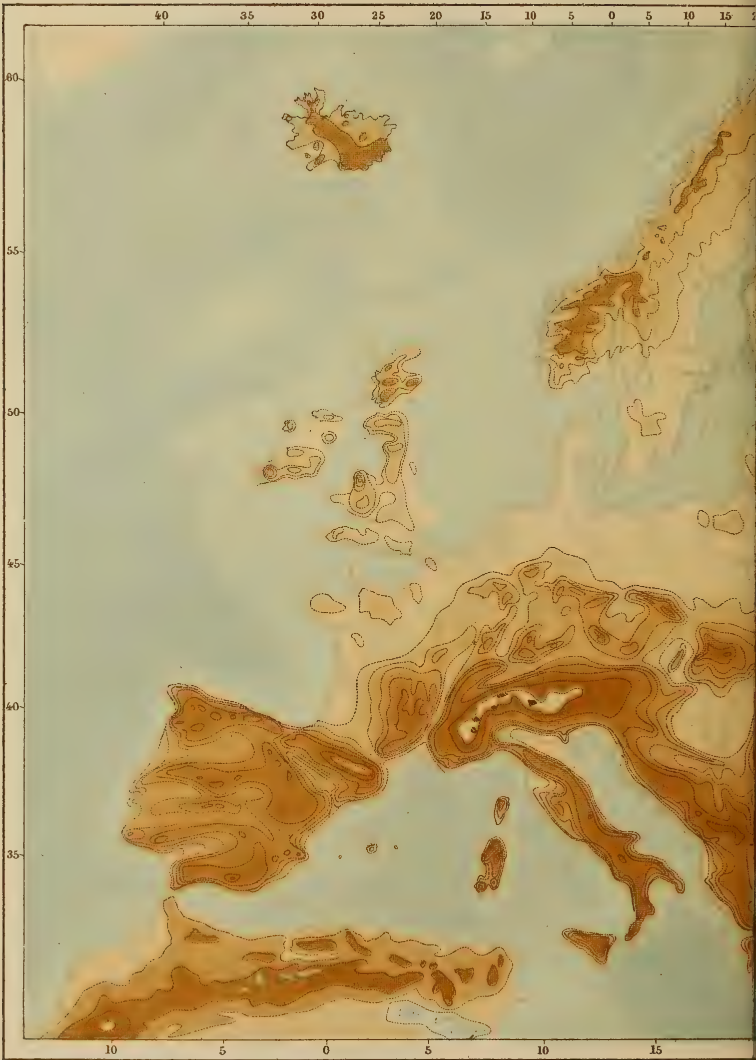

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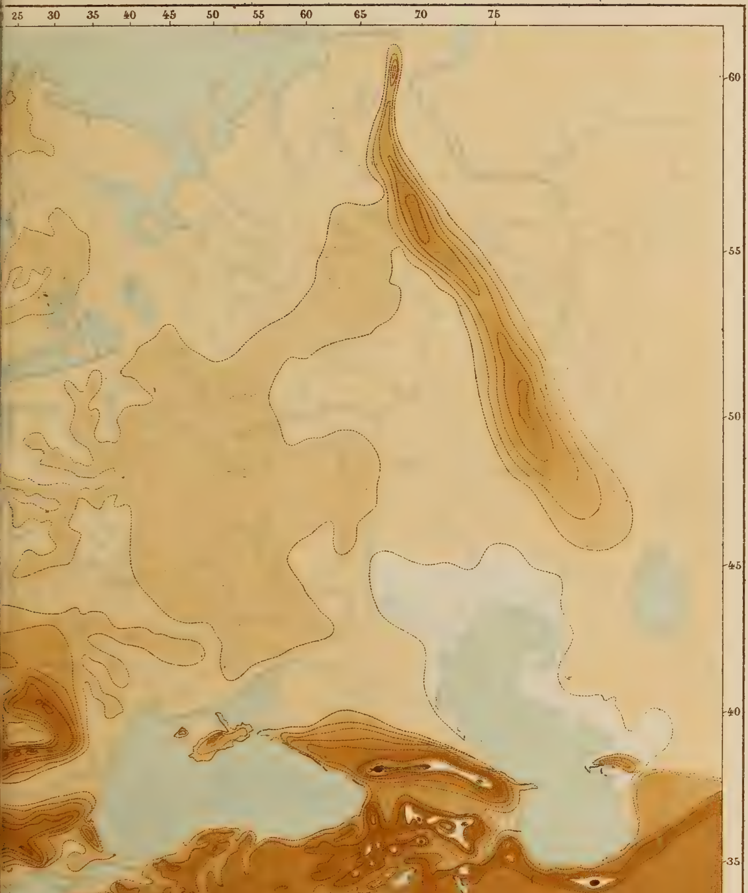

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forms the boundary between the eastern deserts, or the Sahara proper, and the group of western deserts, designated under the general name of Sahel. Farther to the east, the oases of Asben, R'at, and Fezzan, which extend obliquely towards the shores of the Gulf of Sidra, might likewise be considered as the frontier between the two regions.

The Sahel is very sandy. Throughout the greater part of its extent the soil is composed of gravel and large-grained sand, which does not give way even under the foot of the camel. Some of the ranges of sand-hills which rise in this desert are chains of small hills composed of heavy sand which resists the influence of the wind. But in many districts of the Sahel the arenaceous particles of the soil are fine and small. The trade-winds which pass over the desert distribute these sandy masses into long waves similar to those of the ocean, and here and there raise them into movable sand-hills, which overwhelm all the oases lying across their path. Travelling towards the south-west, in which direction they are driven by the wind, the sands reach the northern shores of the Niger and Senegal at many points of their course, and by their incessant deposits gradually drive the waters of these rivers towards the south. To the west, the sand of the desert encroaches also upon the ocean. Off the coast which stretches between Cape Bojador and Cape Blanco —pointed out from afar by the highest dunes in the world—a line of sand-banks extends far out into the sea. These banks are constantly renewed by the desert-wind; and the Arabs who go to collect the waifs and strays from shipwrecked vessels can safely venture out several miles from the shore. A current of sand is therefore constantly passing across the desert from north-east to south-west. But in the vast region of the desert, with its hills and valleys and thousand modifications of the surface, the climate varies greatly. The winds do not blow always from the same quarter, and consequently the sand-dunes frequently change their direction. Those of Erg, which rise to a height of over 1,600 feet between Biskra and R'dames, have been formed by the south-east wind, by which vast quantities of sand are driven forward. On the other hand, the dunes encircling the Shott Melr'ir and neighbouring depressions are found every year nearly in the same place, because the south-east winds prevailing in summer are neutralised by those blowing in winter from the opposite quarter.

Some parts of the Eastern Sahara are equally sandy; but the principal parts of the surface of this desert are occupied by plateaux of rock or clay, and by groups of greyish or yellowish mountains. The chains of sand-hills are numerous, and, like those of the west, they travel incessantly under the impulse of the wind in a south or south-west direction. The rocky plateaux are crossed and recrossed here and there by wide and deep clefts, which are gradually filled by the drifted sand, and into which the traveller runs the risk of sinking, like the mountaineer into the *crevasses* of a glacier. In the hollows, patches of salt take the place of the lakes which in more rainy countries would be found there.

Those districts of the Sahara which are destitute of oases present a truly formidable aspect, and are fearful places to travel over. The path which the feet of camels have marked out in the immense solitude points in a straight line towards the spot which the caravan wishes to reach. Sometimes these faint footmarks are again covered with sand, and the travellers are obliged to consult the compass or examine the horizon; a distant sand-hill, a bush, a heap of camels' bones, or some other indications which the practised eye of the Touareg alone can understand, are the means by which the road is recognised. Vegetation is rare, deprived as it is of the moisture which it requires. The only plants to be seen are the Artemisia, thistles,

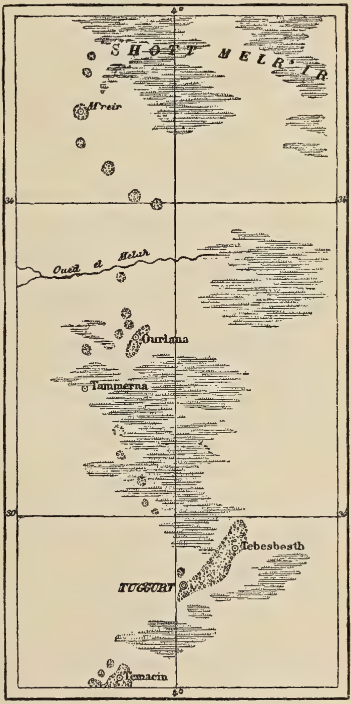
and thorny Mimosas. In some sandy disticts there is a complete absence of all kinds of vegetation. The only animals to be found in the desert are scorpions, lizards, vipers, and ants. During the first few days of the journey some indefatigable individuals of the fly-tribe accompany the caravan, but they are soon killed by the heat; even the flea itself will not venture into these dreadful regions. The intense radiation of the enormous white or red surface of the desert dazzles the eyes; in this blinding light, every object appears to be clothed with a sombre and preternatural tint. Occasionally the traveller, when sitting upon his camel, is seized with the *râgle*, a kind of brain fever, which causes him to see the most fantastical objects in his delirious dreams. Even those who retain the entire possession of their faculties and clearness of their vision are beset by distant mirages; palm-trees, groups of tents, shady mountains, and sparkling cascades seem to dance before their eyes in misty vapour. When the wind blows hard, the traveller's body is beaten by grains of sand, which penetrate even through his clothes and prick like needles. Stagnant pools, or wells, dug with great labour in some hollow, from the sides of which oozes out a scanty and brackish moisture, point out each day the end of the stage. But often this unwholesome swamp, where they hoped to be able to recruit their energies, is not to be found, and the people of the caravan must content themselves with the tainted water with which they filled their flasks at the preceding stage. It is said that in times of great need the travellers have been compelled to kill their dromedaries in order to quench their thirst in the nauseous liquid which is contained in the stomach of these animals. During their expedition to the great Libyan desert, Rohlfs and his companions provided themselves with a large number of camels laden with iron water vessels, which were to be opened only in the last extremity. Nevertheless they had to change their course, and take the route of the Siwah oases.

Terrible stories are also told by the side of the watch-fires of caravans being overtaken when amidst the sand-hills by a sudden storm of wind, and completely buried under the moving masses; they also tell of whole companies losing their way in the deserts of sand or rocks, and dying of madness after having undergone all the direst tortures of heat and thirst. Happily such adventures are rare, even if the accounts of them are at all authentic. Caravans, when led by an experienced guide, and protected by treaties and tribute against the attacks of plundering Arabs and Berbers, nearly always arrive at the end of their journey without having undergone any other sufferings than those caused by the intolerable heat, the want of good water, and the coldness of the nights; for the nights which follow the burning days in the Sahara are in general very cold. In fact, the air of these countries being entirely destitute of aqueous vapour, the heat collected during the day on the surface of the desert is, owing to the nocturnal radiation, again lost in space. The sensation of cold produced by this waste of heat is most acute, and especially so to the chilly Arab. Not a year passes without ice forming on the ground, and white frosts are frequent. During his travels in the country of the Touaregs, M. Duveyrier observed a difference of more than 129° Fahr. between the lowest temperature (24° Fahr.) and the highest (153° Fahr.); but it is probable that the real difference between the extremes of heat and cold amounts to at least 144°.

In all those countries in the Sahara where the water gushes out in springs or descends in streams from some group of mountains, there is an oasis formed—a little green island, the beauty of which contrasts most strikingly with the barrenness of the surrounding sands. These oases, compared by Strabo to the spots

dotted over the skin of the panther, are very numerous, and, perhaps, comprehend altogether an area equal in extent to one-third of the whole Sahara. In the greater part of this region, the oases, far from being scattered about irregularly, are on the contrary arranged in long lines in the middle of the desert. The cause of this is either the higher proportion of moisture contained in the aërial currents which pass in this direction, or, and perhaps principally, the subterranean water which follows this slope, and here and there rises to the surface. Thanks to this distribution of the oases, like beads on a necklace, the caravans dare to venture into the solitudes of the Sahara, their stages being all marked out beforehand by the patches of verdure which in turn rise on the horizon.

Fig. 21.—Weld-R'ir.



The oases are, *par excellence*, the country of date-trees; in the neighbourhood of Mourzouk there are no less than thirty-seven varieties. These trees form the riches of the tribe, for their fruit supplies food to man as well as to beast—to dromedaries, horses, and dogs. Below the wide fan of leaves which quiver in the blue air are thickly growing clumps of apricot, peach, pomegranate, and orange-trees, their branches loaded with fruit, and vines intertwining round the trunks; maize, wheat, and barley ripen under the shade of this forest of fruit-trees, and, lower still, the modest trefoil fills up the very smallest intervals of the soil which is capable of irrigation. In order not to encroach on this precious ground, which is the very life of the whole tribe, the inhabitants construct their houses on the most unproductive land in the oasis, and even on the very verge of the desert. Unfortunately, these wonderful gardens, which the traveller, just emerged from the ocean of sand, looks upon as a place full of enjoyment, are for the most part unhealthy, on account of the constant evaporation of tepid and bad water which the irrigation-drains bring to the foot of the trees. For this reason the Cæsars of the Lower Empire used to send convicts to the oases, in order that they might get rid of them the sooner. But the supply of water, which is so precious to these gardens, is badly regulated; at the time of heavy rains, which are, however, rare in the desert, the brook, suddenly transformed into a river, sometimes destroys the channels and washes away the trees; whereas, if retained in vast reservoirs, this water might be the means of extending the limits of the oasis. New tracts of cultivated ground may even be created by boring artesian wells; this has, indeed, been done in some places, though in a rough manner, by the native tribes. During the twenty years between 1856 and 1876, the French have sunk in the closed basin

of Hodna and in the desert part of the province of Constantine as many as 156 wells, yielding about 60,000 gallons a minute, and nourishing over 200,000 palms. A few strokes of the boring-rod have thus changed the terrible aspect of the desert and adorned it with magnificent groves.

No doubt, if all the subterranean springs of the Sahara were brought to the surface, they might succeed in bringing a great part of it under cultivation, and in course of time in modifying the climate, as they have done in Egypt, by augmenting the quantity of rain and aqueous vapours. Added to this, the examination of the soil and the remains which are contained in it proves that at a recent geological epoch the Sahara was much less sterile than it now is. The tribes of the Algerian Sahara say that at the time of the Romans the Wad-Souf was a great river, but some one threw a spell upon it and it disappeared.

To the east of Egypt, which may be considered as a long oasis situated on the banks of the Nile, the desert begins again, and borders the whole extent of the Red Sea. A large part of Arabia presents nothing but sands and rocks, and towards the south-east, in the Dahna, there are solitudes which no traveller, either Arab or European, seems yet to have crossed. To the north and east stretch the *Nefuds*, or "daughters of the great desert," which are much smaller than the Dahna, but are nevertheless formidable tracts to travel over. In one of these regions, which was crossed by Palgrave, the mass of sand, formerly deposited there by the marine currents, attains its greatest depth; in certain places it is 330, 400, and even 500 feet deep. It can be measured by the eye by descending to the bottom of the funnel-shaped cavities which the springs of water, spouting out of the adjacent granite or calcareous rock, have gradually hollowed out in the bed of sand. This enormous bed of material, which represents chains of pulverized mountains, does not exhibit an even surface, as one would expect, but throughout its whole expanse presents long symmetrical undulations, similar to those waves which roll in the Carribean Sea under the even influence of the trade-winds. These waves stretch from north to south, parallel to the meridian. It is probable that they are owing to the movement of the earth round its axis. The solid rocks beneath unresistingly obey the impelling force which carries them towards the east, but the movable sands which are above them do not allow themselves to be carried away with an equal rapidity; each day an infinitesimal quantity remains behind and seems to glide towards the west, like the waves of the ocean, the atmospheric currents, and everything that is movable on the face of the globe. The parallel furrows of sand in the Nefud certainly rise to a greater height than those of the other deserts, and differ much in their aspect from the smaller waves of sand formed by the wind; but the reason is, that the bed of sand in this region is of a very great bulk, and because at this point the swiftness of the globe nearly attains its maximum, on account of its vicinity to the equator. However, the hypotheses advanced on this subject cannot claim more than a secondary value, for the statements made by Palgrave have not been confirmed by Blunt, who has more recently travelled along somewhat different lines of route.

To the east of the Arabian peninsula the chain of deserts is prolonged obliquely across Asia. The principal part of the Iranian plateau, occupying a quadrilateral space surrounded by mountains which stop the rains in their passage, consists of sterile solitudes, some covered with saline beds, the remains of dried-up lakes, others spread over with shifting sands which the wind blows up into eddies, or dotted over with reddish-coloured hills, which the mirage renders either nearer or more distant to the eye than they really are, incessantly modifying them according

to the undulations of the atmosphere. This plateau is separated from the steppes of Turkestan only by the Elburz Mountains, and is continued towards the east by the deserts of Afghanistan and Beluchistan, which are not so large, and much easier to travel over. Even the rich peninsula of India is protected by a belt of sterile tracts situated on the right and left of the Indus. Between each of the five rivers (Punjab), which by the union of their waters form the great river, stretches a line of steppes in which the torrent-waters of the mountains are soon lost. The soil of these steppes is nearly everywhere barren, except on the edge of the irrigation canals constructed by the inhabitants at a very heavy outlay. Southwards, the whole space comprised between the Rajputana hills, the old course of the Indus, and the argillaceous plain of the Rann of Katch, is covered, like the Nefud, with sandy dunes. The Thar, as this region is called, is sometimes erroneously spoken of as the "Great Desert of India."

There are also a few tracts where the extremely fine sand may be sounded like water to a depth of over 300 feet. One of these regions of liquid sand lies in the south of Hadramaut, and although the extraordinary statements made by the traveller Wrede regarding this formidable "quagmire" seemed exaggerated, they have been fully confirmed by more recent explorers, and especially by Munzinger. M. Rudaire also has discovered in one of the Tunisian shotts an underground bog covered with a thin sandy and saline layer, which gave way when stepped upon.

Beyond the mighty central group whence radiate far and wide the mountain-chains of Asia, the steppes and deserts, mutually alternating according to the topographical conditions and the abundance or scarcity of water, extend over a space of more than 1,850 miles between Siberia and China proper. The eastern part of this belt is called, according to the languages, Gobi or Shamo, that is to say, the desert *par excellence*, and from its enormous dimensions corresponds with the Sahara of Africa, situated exactly at the opposite extremity of the long chain of solitudes which stretches right across the Old World. The mirage, the moving sand-hills blown up into eddies, and many other phenomena described by African travellers, are found in certain districts of the Gobi, just the same as in all other deserts. But the cold here is exceptionally intense on account of the great height of the plateaux, which is on an average 4,950 feet, and the vicinity of the plains of Siberia, which are crossed by the polar wind. It freezes nearly every night, and often during the day. The dryness of the atmosphere is extreme; there is hardly any vegetation, and a few grassy hollows are the only oases of these regions. From Kiakhta to Pekin there are only five trees for a distance of 400 to 500 miles, which is the width of the desert in this part of Mongolia. The Gobi, however, like the Sahara, was formerly covered by the waters of the ocean; even on the elevated plateaux old cliffs may be noticed, the bases of which are worn away by the waves, and long strands of round shingle stretch around the area which was formerly occupied by a now vanished gulf

CHAPTER XV.

PLAINS AND DESERTS OF THE NEW WORLD.—COMPARATIVE HUMIDITY OF THE AMERICAN CONTINENTS.—DISTRIBUTION OF SAVANNAHS AND STERILE TRACTS. —THE PRAIRIES OF NORTH AMERICA.—THE LLANOS AND PAMPAS.

THE American continent, being narrower and more exposed throughout its whole extent to the moist sea-breeze than the larger mass of the Old World, presents, therefore, but a very small number of districts in which the dryness and sterility are to be compared to certain parts of the Sahara and Arabia. It is true that plains occupy a relatively much larger area in the New World than in the continents of Asia and Africa; but they are for the most part regions which, from the abundance of water and the deposit of fluviatile alluvium, have become very fertile. Thus the low grounds which extend along the two banks of the Mississippi, and especially the district lying along the edges of the Amazon and its large tributaries, are covered with immense forests, which are perfect seas of trees and creepers, into which no one would dare to venture without a guide, even if they are not completely inaccessible to all but the native, armed with his *machete*. The *selvas* of the Amazon are the regions where vegetation exhibits its richest exuberance, spread over the most extensive area.

Plains which are devoid of trees occupy very considerable tracts of land in the two Americas, and, notwithstanding the absence of all forest vegetation, several of them being formed of fluviatile or lacustrine alluvium, are extremely fertile. In consequence of the composition of the soil, the distribution of the rainfall and water-courses, and perhaps, also, in obedience to some still unknown law governing the distribution of plants on the surface of the earth, savannahs of the various grasses alternate abruptly with virgin forests. This unexpected contrast between the wall of trunks, through which the sight cannot penetrate, and the unbounded extent of the grassy plain waving in the breeze, is one of the most striking spectacles imaginable. In the basins of the Mississippi, the Amazon, and the tributaries of the La Plata, these sudden transitions from forest to savannah are frequently found. Next to the great rivers and large sheets of marshy water, they are the most prominent feature of the landscape in the plains of the New World.

Taken as a whole, the grassy expanses of America are all—like the *landes*, the steppes, and the *tundras* of the Old World—regularly arranged in a line parallel to the axis of the continents themselves. In North America, they are contained in the vast central basin formed by the Alleghanies and the first spurs of the Rocky Mountains. In South America they likewise occupy a part of the depression in the middle of the continent between the plateaux of the Guianas and Brazil and

the first groups of the Andes. Thanks to the rainy sea-breezes which blow over these plains, either from the north or south, vegetation is here kept up, at least during several months of the year; and nowhere, even in the less fertile districts, are real deserts to be found. These plains, which, as in Africa and Asia, are likewise arranged in a line parallel to the belt of savannahs and to the continental axis of America, are all situated on the western side, on the slopes or in the inner basins of the Rocky Mountains and the Andes. They are, however, comparatively inconsiderable, and intersected by fluviatile valleys, some of which terminate in lakes without an outlet, whilst others run down to the sea.

The savannahs or prairies of Illinois and the other Western States of the American Republic resembled, not long since, the Magyar *puszta* and the grassy steppes of Russia, except as regarded the difference of vegetation attributable to climate. Some of those plains, which, at a former geological epoch were covered by the waters of Lake Michigan, have not yet been transformed into cultivated fields, and they have a uniform and level surface like that of a lake. The flowering grasses growing on them wave and quiver in the wind like the ripple of the waves, and the clumps of trees are dotted about like islands. Here and there these islands are grouped into archipelagos, and the arms of the prairies which surround them fork out and unite again like the arms of a grassy sea; one single prairie, situated in the centre of the state of Illinois, is so vast that, as far as the eye can reach, not one of these thick clumps of trees appears in sight. But in consequence of the very rapid colonisation of the Western States, these countries are every day changing their aspect. The traveller therefore must not delay if he wishes to survey these immense prairies, where the horizon, as on the sea, is limited only by the rotundity of the globe—where the grasses are so high that they reach up to, and bend over, the head of the traveller, and the roebuck can dart through them without even being perceived. Ere long these prairies will have ceased to exist, save in the narrations of Cooper the novelist; the furrows of the unrelenting ploughshare will have converted them all into cultivated fields. The Americans are active in turning them to account and in taking possession of this fertile land. The country, which is thoroughly surveyed, is divided into townships of about six miles on each side, and sub-divided into square miles, which are again separated into four parts. All these quadrilateral spaces are so accurately set as to aspect that each of their sides faces one of the four cardinal points. The purchasers of small or large squares never allow themselves to deviate from the straight line; like true geometricians, they construct their roads, build their cabins, dig their ponds, and sow their turnips in the direction of the meridian or the equator. Thus the prairies, once so beautiful with their gently undulating contour and their misty distances, now bear a strong resemblance to an immense chess-board. Even the railway engineers will hardly make up their minds to cross the degrees of longitude in an oblique direction.

In the southern continent, the regions which correspond with the prairies of the United States are the *pampas* of La Plata and the *llanos* of Columbia. These latter expanses, so well described by Humboldt, are probably, of all the plains in the world, those which exhibit in their appearance the most striking contrast, according to the different seasons of the year. After the rainy season, the plains, which extend over the immense zone contained between the course of the Orinoco and the Andes of Caracas, Merida, and Suma-Paz, are covered with thick grass, and graminaceous and cyperaceous plants, among which the sensitive and other species of Mimosa here and there exhibit their delicate foliage. Horses and oxen wander by millions over these magnificent pastures. But the soil gradually dries up, the

watercourses become exhausted; the lakes change into pools and then into sloughs, in the mud of which crocodiles and serpents delight to wallow; the clayey ground shrinks and cracks, the plants wither, and are torn to shreds by the wind; the cattle, driven by hunger and thirst, take refuge in the neighbourhood of the great rivers, and multitudes of their skeletons lie bleaching on the plain. This is the special time when the *llanos* most resemble the deserts of Africa, which are situated

Fig. 22.—The Pampas.

farther from the equator on the other side of the Atlantic. All at once, the storms of the rainy season inundate the soil, multitudes of plants shoot out from the dust, and the immense yellow expanse is transformed into a flowery meadow. The rivers overflow their banks, and the inundations will sometimes extend over a breadth of hundreds of miles; the ancient islands, called "tables," or *mesas*, form the only land which appears above the troubled sheet of waters.

The *llanos* of Venezuela and New Granada have an area estimated at 154,000

square miles, nearly equal to that of France. The Argentine *pampas*, which are situated at the other extremity of the continent, have a much more considerable extent, probably exceeding 500,000 square miles. This great central plain, which forms one of the most remarkable features of South America, stretches its immense and nearly horizontal surface over a length of at least 1,900 miles, from the burning regions of tropical Brazil to the cold countries of Patagonia. In so vast a territory the climate and vegetation must necessarily differ very much; and yet a great monotony prevails, on account of the horizontal character of the ground and the want of water. The rivers of the *pampas*, the Pilcomayo, the Vermejo, and the Salado, which rise in the Andes and the Sierra Aconquija, ultimately reach the great fluviatile artery of the Parana, but not without having lost a large part of their waters on the road, owing to the evaporation in the lagoons and marshes. Farther south, the Rio Dulce, which also rises in the ravines of Aconquija, is lost in a salt lake at some distance to the west of the Parana. In the same way all the watercourses of the provinces of Catamarca, Rioja, San Juan, Mendoza, and Cordova, growing smaller in proportion to their distance from the mountains, ultimately spread out into marshes or break up into pools; the sand of the desert gradually absorbs them. The Rio-Quinto, which formerly reached the sea, and emptied itself to the south of the estuary of La Plata into the bay of San-Borombon, now stops at about the middle of its former course; but to the east some lagoons connect it with the sources of a small stream, which may be considered as the Lower Quinto. The diminution of rains and the increase of evaporation during the present geological period have resulted in severing the river into two parts.

The western plains, which partly surround the Cordovan group, are dotted over with prickly plants, brooms, mimosas, and other shrubs of scanty foliage. There is only a short turf growing upon the clayey and compact soil, and here and there vast salt plains, completely devoid of vegetation, glitter in the sun. These are real deserts, which were formerly crossed by travellers in caravans, just as in the solitudes of Africa and Persia. The carriages which now run regularly between the towns on each side of the plain go across in a straight line, and their drivers do not even take the trouble to trace out a road. Farther to the east, the *pampa* proper extends from north to south, between the Salado and the regions of Patagonia. Here are situated the immense and celebrated pasture-grounds which form the wealth of the Argentine Republic, on account of the cattle which overrun it by hundreds of thousands, and, indeed, millions. The grassy surface seems to be completely flat; no object interrupts the majestic uniformity of the landscape, except, perhaps, a herd of oxen, the yellow wall of some *estancia*, or a solitary tree spared by the hatchet of the *Gaucho*. Pools, some brackish or saline, others filled with fresh water, are scattered over the prairie, and continue the wavy covering of grasses with their tufts of rushes and reeds. To the north of the Salado, the great sea of grass is succeeded by thickets of mimosas and other prickly shrubs, which surround the small savannahs. Lastly, beyond the windings of the Pilcomayo, bunches of palm-trees are seen here and there among the clumps, and the *pampa*, called in this district the *Great Chaco*, ultimately merges in the large *selvas* in the basin of the Amazon by swampy grounds and isthmuses of forest.

Most of the Australian continent also consists of desert plains which cannot be traversed without risk. Immediately west of the New South Wales uplands stretch the lowland tracts watered by tributaries of the Murray, and in their general aspect resembling the steppes of South Russia and the prairies and pampas

of America. But in the heart of the continent, where the rainfall is less copious, the land becomes more arid and inaccessible. Here rocky ranges and waterless ravines alternate with stretches of reddish clay, covered here and there with patches of almost leafless scrub. Large depressions, towards which converge the beds of intermittent streams, like the wadies of the Sahara, appear to have formerly been lacustrine basins, although now rarely flooded except by saline or brackish waters. Usually they contain nothing but a blackish mud, which yields to the step of the passing wayfarer. Many daring explorers have already perished while crossing the Australian deserts in search of fresh pasture-lands, and the work of discovery will doubtless still claim many more victims.

CHAPTER XVI.

AMERICAN DESERTS.—THE GREAT BASIN OF UTAH.—THE DESERT OF COLORADO.—THE ATACAMA AND THE PAMPA OF TAMARUGAL.—DEPOSITS OF SALT, SALTPETRE, AND GUANO.

IN North, as in South America, the deserts proper lie to the west of the continent, and occupy the basins commanded by the parallel or divergent walls of the Rocky Mountains. In both hemispheres it is the want of rain which is the cause of the sterility of these expanses, to which the moist winds cannot obtain access, on account of the high mountains by which the plains are surrounded; but, by a remarkable contrast, the rains in the northern continent, which are stopped *en route* before reaching the deserts, are those brought by the clouds from the Pacific, and in the southern continent those which come from the Atlantic with the trade-winds. In the north, the ridges of the western chains, the coast range, and the Sierra-Nevada are the barriers which arrest the moisture of the atmospheric currents of the neighbouring ocean; in the south it is, on the contrary, the eastern groups of the Cordilleras, which, by opposing the course of the Atlantic trade-winds from the north-east and south-east, are the cause of the barrenness which exists on their opposite declivities. Besides, in both continents, most of the deserts, whether plains or plateaux, seem to have been, at some former geological epoch, levelled by the waters of some inland sea.

The most northerly of these American deserts occupies, to the west of Lake Utah, a part of the space called the "Great Basin," and is comprised between the principal chain of the Rocky Mountains and the Sierra-Nevada of California. The desert of Utah is an immense surface of clay, dotted over with thin tufts of Artemisia; in certain places, however, it exhibits no trace of vegetation, and resembles a causeway of concrete intersected by innumerable clefts, forming nearly regular polygons. In the midst of these solitudes no rivulet flows, and no water-spring gushes forth; only after journeying for many a long hour the traveller sometimes comes upon some field of crystallized salt, a white expanse on which the clouds and blue sky are reflected as on the surface of a lake. On the extreme horizon some volcanic rock may be seem, like great scoriæ, half-veiled by warm atmospheric columns, quivering like the air over the flame of a hot brazier. Across these vast plains, inhabited only by a prodigious quantity of extraordinarily shaped lizards, the road employed by the emigrants used to pass, which was so soon destined to be supplanted by the Pacific Railway from New York to San Francisco. Since the discovery of California thousands of men have perished in this desert, and innumerable horses and oxen have died of thirst; the right direction of the road is

indeed recognised by their bones lying scattered over the ground. The traveller is obliged to stop during the night for fear of losing his way when he no longer hears the sound of the skeletons crushing under the feet of his steed.

Separated from this desert by chains of mountains, among which are to be found several shady valleys enlivened by brooks, there are some solitudes extending southward which are less sterile than those of which we have just spoken. The only vegetation which some of these exhibit is a few scanty brambles here and there creeping over the ground; others are clothed with a thin foliage of thorny shrubs; but the greater part of the bare rocks or clay in these desert tracts appears just the same as when it first emerged from the water. Only a few *pitahayas,* like gigantic candelabra, stand solitarily at considerable distances from each other. Their trunks, which rise to the height of from 48 to 60 feet, are as straight as columns, and from the base to the summit have a nearly uniform thickness, equalling sometimes the size of the human body; the branches, to the number of two or three only, jut out from the trunk at a right angle, and then stand erect, like the branches of an enormous chandelier. Owing to the regularity of their shape, their parallel sides covered with thorns, and their grayish-green colour, these curious plants seem to be a kind of intermediate substance between the tree and the rock, and give to the landscape an aspect which is both fantastic and repulsive. In some regions hundreds of miles may be traversed across the mountains, valleys and plains, and during the whole journey no other species of terrestrial vitality can be seen but these immense *pitahayas.* Even this amount of vegetation is wanting in the most sterile districts of New Mexico and Arizona. Thus the desert of Colorado, situated near the mouth of the river bearing the same name, in the Gulf of California, is a totally barren expanse of clay and sand. In the evening, when the sun is setting far away behind the ruddy mountains and darting its rays across the dusty atmosphere, the traveller, when encamped in the bed of some dried-up river on the border of this immense plain, which was, indeed, formerly a lake, might easily fancy that he sees stretching before him the surface of a sea of fire.

The solitudes of the Andes most resembling the desert regions of the Old World and of the United States are the elongated plateaux which rise one above another between the sea and the principal chain of the Andes, in southern Peru and on the frontiers of Bolivia and Chili; such as the *pampas* of Islay and Tamarugal and the desert of Atacama. The *pampa* of Tamarugal, so called from the *Tamarugos* or tamarisks which grow in the hollows where some moisture oozes out of the soil, has a mean altitude of from 2,900 to 3,900 feet. It is a plain nearly covered with beds of salt, or *salares,* which are worked like rock quarries. The strata of salt are so thick, and rain is so rare upon the plateau, that the houses of the village of Noria, which are inhabited by the workmen, are entirely constructed of blocks of salt. Some deserts, situated to the east of the Tamarugal, on more elevated plateaux, contain a still larger quantity of salt. The *pampa* of Sal, which is overlooked by the volcano of Isluga, has a mean altitude of not less than 13,800 feet, and its whole extent, which is 125 miles long and from 9 to 24 miles wide, is perfectly white. The depth of salt deposited upon this plateau varies from 5 to 16 inches, according to the undulations of the ground.

Whence do these immense masses of salt proceed? Doubtless from the sea or ancient lakes which formerly covered these countries, and have been gradually emptied by the rising of the soil. Saline matter saturates even the rocks and clays, for a film of salt again forms by efflorescence on all the ground in the desert from which crops have previously been taken. The district of Santa-Rosa, which was

completely cleared of salt in 1827, was all white again and fit for working after a lapse of twenty-three years. Sea-salt is not the only production of these immense natural laboratories; but nitrates, sulphates, carbonate of soda, borates of soda and lime, are also found there, and increase every year in thickness, thanks to the intermittent torrents which sometimes descend loaded with *débris* from the adjacent Cordilleras. Saltpetre is also procured from the *pampa* of Tamarugal, and is the article which, during all the wars of Europe and America, gave such great commercial importance to the town of Iquique.

About the middle of the eighteenth century, an Indian, named Negreros, discovered the existence of saltpetre in the *pampa;* having lighted a fire of brushwood upon the soil, he perceived that the ground was melting, and that a stream issued from the midst of the firebrands and cinders. From this date they began to work these beds; but it is only since the last twenty-five years especially that this branch of industry has been carried on to any considerable extent. According to Smith, the engineer, the beds of nitrate occupy in the *pampa* of Tamarugal an area of 483 square miles; in some spots, where the mass is not less than 10 feet in depth, a ton of saltpetre may be taken from a square yard of ground; but reckoning only on a product of 110 lbs. a yard, it is found that the total quantity of saltpetre at present contained in the superficial beds of the *pampa* is not less than 63 millions of tons, or enough to supply the requirements of trade for 1,393 years, if the working does not exceed, on an average, that of the year 1860.

The desert of Atacama, the largest of all those in South America, occupies a wide belt of plateaux between the shores of the Pacific and the high rampart of the Andes, which separates Bolivia from the Argentine Republic. This expanse of reddish-coloured rocks and crescent-shaped shifting sand-hills is so repulsively desolate a place, that the conquerors of Chili, whether Incas or Spaniards, never made up their minds to venture into it in going along the sea-coast; they have been obliged to pass far into the interior, by the plateaux of Bolivia, and to twice cross the Andes before entering the Chilian valleys. Not long since, men of science were the only travellers who dared to enter the desert of Atacama. Nevertheless this formidable-looking country also possesses, like the *pampa* of Tamarugal, great natural riches, which will not fail to summon the labour of man and all the progress of civilisation to these desolate regions. Besides salt and saltpetre, this desert produces guano—that is, heaps of the almost exhaustless droppings of all the sea-birds which settle down in clouds upon the sea-shore. During the course of centuries the ordure has accumulated into perfect rocks which the sun dries up, and the surface of which is but rarely softened by rain. These masses of *detritus*, which are, to all appearance, useless upon these barren shores, are life itself to the countries of England, France, and Belgium, which have become exhausted by the extent of cultivation; and, consequently, this substance constitutes a most important element of national commerce. The principal treasure, or national bank, so to speak, of the Peruvian Republic is represented by the heaps of excrement which cover the Chincha Islands off the coast of Callao. According to the various calculations, from 12 to 15 millions of tons of excellent guano are to be found there, a quantity which is worth to Peru more than 80 millions of pounds sterling, an amount which, if well laid out, would enable the happy possessors to construct a magnificent system of railways, and to build a school in each of their villages, But they must be quick about it, for the treasure of guano will probably be exhausted in twenty years; already, since the year 1866, the northern island has been cleared down to the solid rock.

CHAPTER XVII.

DIFFERENCE BETWEEN PLATEAUX AND PLAINS.—MATERIAL IMPORTANCE OF PLATEAUX IN THE ECONOMY OF THE GLOBE.—DISTRIBUTION OF ELEVATED REGIONS ON THE SURFACE OF CONTINENTS.

NOTWITHSTANDING the variety of aspects and vegetation which is introduced by the difference of climate, low-lying lands, among which, it must be remembered, are included so many sterile deserts, play a much less important part in the history of the globe than the more elevated portions of the emerged surface of the earth. Both the organization and the vitality, so to speak, of continents are due to the external relief of the planet; these inequalities in the surface are also the cause of the varied development and distribution of climates, water-courses, products, and populations over the whole world.

All the elevated portions of continents and islands may be naturally divided, according to the height and inclination of the land, into plateaux and mountain systems. By the word *plateau* we now usually understand some extent of land raised to a considerable elevation above the level of the sea, but the surface is not always uniform and level, as the name would seem to indicate. When the surface is very irregular, either furrowed by deep ravines, or dotted over with hills and mountains, the ideal plain which would pass through the bases of all the mountains at a height to allow for filling up all the intervening depressions is considered as the superficies of the plateau. There are, however, some plateaux which are almost perfectly level, such as the staked-plains of Texas and some portions of the Utah basin.

Low-lying lands, also, very often present a surface undulated with hills and valleys, and connected with higher plateaux either by gradual slopes or by a succession of terraces, which may be looked upon either as the rise of the plain or the descent of the plateau. The difference existing between high and low lands is purely relative; we can only define them by saying that a plain is a surface comparatively level, and commanded on one or all sides by more elevated tracts, and that plateaux exceed in height the land surrounding them. The ground, which would be a plain for the inhabitants of the mountains above it, would be a plateau for those who live on a lower level. Thus, in Louisiana, where the surface is so frequently inundated, undulations of the ground which are almost imperceptible to the eye go by the name of hills, because they are not invaded by the floods of water; also, on the level surface of the sea, the blocks of ice detached from the glaciers of Greenland and Spitzbergen are commonly called mountains of ice, or icebergs. Agassiz, when contemplating the heights of Obydos, in the

midst of the interminable plains of the Amazon, fancied that he was again looking upon the sublime mountains of his native country.

The absolute height of the several stages of elevation of the land is not, therefore, the chief thing taken into account in the geographical division into plains and plateaux, but the relation which they bear to the continental mass of which they form a part. The country of North Hindustan is more elevated than the plateaux of Suabia and Bavaria, and yet it must nevertheless be considered as a plain, because it belongs to a continent the general features of which are gigantic in comparison with those of Europe. In both parts of the world the respective proportions are retained between the various stages of the continental edifice. The plateaux of Asia correspond to those of Southern Germany; the Himalayas remind us of the Alps; Hindustan, with its plains and mountains, is the counterpart of the Italian peninsula.

Although plateaux, precisely on account of their size and the grandeur of their proportions, make less impression on the human mind than a steep and rugged mountain-chain, towering up between two countries like an enormous rampart, nevertheless in their importance to the vitality of the globe they are certainly superior to any other features in the continental configuration. If the emerged surface of the planet were perfectly level the most depressing uniformity would everywhere reign. The same phenomena would be produced over the whole extent of the continental surface from one ocean to the other; the winds, meeting with no obstacle in their course, would sweep round the globe with an ever-equal motion, like the long bands of cloud which the telescope discovers on the planet Jupiter. There would be none of those elevated masses which, by their transverse position to the natural course of the winds, produce an interruption of the equilibrium, and drive back the atmospheric currents in every direction. There would be none of those great refrigerators, as they may be called, which condense the moisture in the clouds, storing it in their reservoirs of ice and snow. Rain would fall everywhere to nearly an equal extent, and the water, finding no declivity along which it might be carried off to the ocean, would stagnate in putrid marshes. A perfect equilibrium of the forces of nature would have as its effect universal stagnation and death. Supposing that men could exist on such an earth as this, the uniformity of one great plain would be far from affording them any greater facilities for mutual communication; they would, on the contrary, remain scattered round their miserable lagoons in all their primitive barbarism. The migrations of whole nations down the inviting slope of some of the vast continental plateaux, in quest of a new country, like a great river seeking the sea, could never have taken place. All civilisation would have been impossible. Perhaps, as some geologists think, the surface of the globe was uniform and without any prominent relief, when the ichthyosaurus swam heavily through the marsh-pools and the pterodactyl spread his sluggish wings over the reed-beds. It was then an earth for reptiles, it could not be a world for men.

If the great plateaux of the globe had been arranged round the Arctic Frozen Ocean, and their long slopes had gradually sunk towards the Indian and Pacific Oceans, the full development of humanity would have been equally impossible. In the north the altitude of the plateaux would have doubled the cold of the frozen zone; all organic life, even that of the most rudimentary plants, would have probably ceased to exist, and, doubtless, the freezing winds, sweeping down from this citadel of snows, would have changed into a second region of ice those temperate countries which are now the fields of so many varied products, and

where so many powerful nations have taken their rise. The only habitable lands would be the islands of the South Seas and the tropical regions of the continents, if, indeed, man could exist at all in a climate where overwhelming heat would be succeeded by icy winds blowing down from the lofty plateaux of the north. But, even supposing that isolated tribes could have found a footing in these countries, mankind in a general sense could not have existed; for by the word mankind we must not understand merely a multitude of scattered individuals, but the whole human race, having a full self-consciousness and knowledge of its destiny.

Whatever may have been the geological causes of the present distribution of plateaux over the various continents, the following remarkable fact must be recognised—that their height increases in proportion to their proximity to the torrid zone, as if the rotation of the globe had caused, not only the equatorial enlargement of the planetary mass, but also the elevation of the continents themselves. In the Tropic of Cancer, the mean altitude of the plateaux is nearly equal to that of the mountains in the temperate zone, whilst the plateaux of the latter are, on the average, the same height as the mountains of the polar zone. In consequence of this distribution of the various high lands, it comes to pass that, in every latitude, certain portions of each continent exhibit an epitome of all the climates which succeed one another over the circumference of the planet from this latitude to the poles. Owing to these plateaux and the mountains which crown them, the Iberian peninsula, Turkey, and Asia Minor enjoy, at various points of their surface, all the varieties of a temperate climate, and thrust their loftiest peaks into cold regions almost similar to those of the poles. In countries of this sort the traveller can change both the climate and the features of nature round him by a journey of a few days, or even sometimes of a few hours; whilst at sea, he would have to make a voyage from the tropics to the icebergs of the poles if he wished to traverse the corresponding stages of climate. The fact of the gradually increasing elevation of plateaux as we go south tends actually to double the number of the zones in the middle latitudes. A polar climate is, as it were, placed above the temperate climate. In Hindustan, three zones of temperature merge into each other on the slopes of the Himalaya, the lofty southern boundary of the Asiatic plateaux. The plains beneath, where vast rivers flow down to the sea and impenetrable forests extend over mighty tracts, are inhabited by an almost innumerable population; higher up, we find mountain torrents, long avenues of firs, and flocks wandering over wide pastures; higher still, there is little but brushwood, mosses, snow, and masses of ice. The function of these high lands in the economy of the globe is to bring down the north into the very bosom of the south, and to unite within a limited space all the climates of our planet and all the seasons of the year.

CHAPTER XVIII.

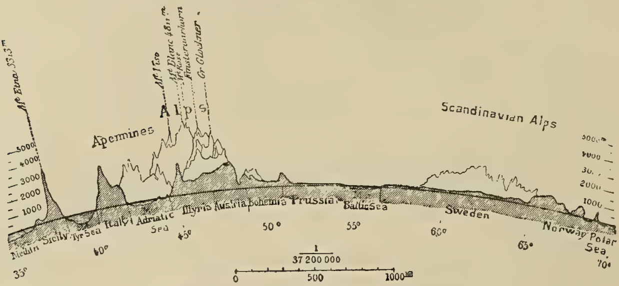
THE GREAT PLATEAUX OF CENTRAL ASIA AND THE GATE OF THE HINDOO-KUSH. —PLATEAUX OF EUROPE; THEIR SYMMETRICAL ARRANGEMENT.—PLATEAUX OF THE TWO AMERICAS.—SIMILARITY BETWEEN THE CLOSED BASIN OF BOLIVIA AND THE DISTRICT OF UTAH.—PLATEAUX OF AFRICA.

PLATEAUX, like the continents themselves, exhibit an organisation more or less rudimentary and a shape more or less articulated, and therefore their importance as agents in the vitality of the globe proportionately varies. Thus, the great plateaux of Central Asia, which may be looked upon as the very skeleton of the continent, exercise, it is true, an influence of the very highest order in the general economy of the earth, but they are almost cut off from all the rest of the world; their water-courses run into inland basins, without any outlet to the sea, and the nations which inhabit them live in a state of almost perfect isolation from the other peoples of the earth. The chief group of plateaux, bounded southwards by the Karakorum range, northwards by the Trans-Alai and the Alai, is the so-called Pamir, or "Roof of the World," which is connected by border chains with the great Asiatic mountain-systems of the Himalayas, Kuenlun, Thian-Shan, and Altaï, enclosing the deep depression of Chinese Turkestan and the great Mongolian desert of Gobi. Among these elevated ranges there are some, as the Dapsang and the Boullon, resting upon the Kuenlun, which exceed 16,400 feet in mean height. Round the greatest part of its extent this enormous fortress of plateaux is rendered almost inaccessible by its formidable girdle of mountains, snows, and deserts; only towards the north-west, between the Thian-Shan and the Altaï, several depressions in the surface open out a road through which, some centuries back, the terrible Mogul horsemen poured down to enter upon their course of devastation through Asia Minor and Eastern Europe.

At one of its angles, the great quadrilateral plateau of Central Asia borders upon another elevated tract, of smaller dimensions but of nearly similar shape; this is the territory of Iran, which, although likewise in great part made up of deserts, does not form so much of a prison to the people who inhabit it as the high grounds situated more to the east. On the north it has several outlets towards the plains of Turkestan and the Caspian Sea, on the west towards the valleys of the Tigris and Euphrates, and it is also connected with the mountain-systems of Asia Minor—the long-reaching peninsula projecting between the two European seas. It is noteworthy that just in the very vicinity of the central knot of mountains where the two great plateaux-systems of Mongolia and Iran are united, the principal portal of the Aryan nations is situated—the defile through which passed the

flux and reflux of wars, migration, and commerce. By a singular geographical contrast, this vital knot of the continent of Asia is at the same time both the spot where the two great plateaux join one another, and also where the plains of Hindustan communicate with those of Turkestan and the Caspian. The diagonals both of the high and low-lying lands of Asia cross at right angles on this point of

Fig. 23.—Section of Europe from South to North.

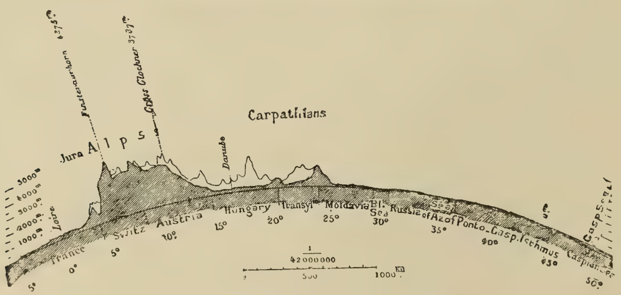


Scale of heights a hundredfold that of distances.

the Hindu-Kush. Here, too, is found, as regards the history of mankind, the most remarkable spot of the whole earth.

In Europe, also, the arrangement of the most considerable plateaux exhibits a singular symmetry. In the same way as in the continent of Asia, all of them, with the exception of the narrow plateaux of Southern Norway, are situated in the south of Europe, and bounded on one side by a chain of mountains. On the west there is the plateau of Spain, backed up by the great rampart of the Pyrenees, the

Fig. 24.—Section of Europe from West to East.



Scale of heights a hundredfold that of lengths.

mean height of the plateau being about 1,980 feet; in Central Europe there is the plateau of Suabia and Bavaria, commanded on the south by the lofty Alps of Switzerland and the Tyrol; on the east there are the high lands of Turkey, situated all along the southern base of the Balkan range. Thus the central plateau of the three extends northwards from a system of mountains, whilst, by a kind of polarity, the two others, situated at the two extremities of Europe, are at the south of the range which serves as their base of support. These elevated districts are, moreover,

much more richly organized than those of Asia, and call to mind the form of the continent of which they form a part, indented as it is with its numerous bays and peninsulas. These plateaux also possess their promontories, which push out far into the plains; wide valleys, too, break a way into their elevated levels, thus providing numerous outlets to the peoples which inhabit the body of the plateau and the country surrounding it. By means of their diversified outlines, the elevated countries of Europe are in no way isolated from the rest of the continent; in no

Fig. 25.—Indented Plateau of Nantua—Department Ain.

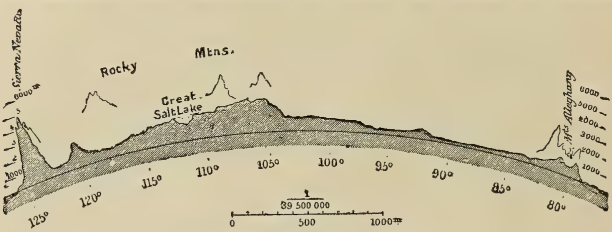
place are the rivers compelled to accumulate in stagnant lakes; every drop of water, every product of the soil, and every man that dwells there, can find an easy pathway to the surrounding plains.

The plateaux of the two Americas are of much greater altitude than those of Europe, and thus correspond to the continents on which they stand. With the exception of the secondary plateaux of the Alleghanies, the Guianas, and Brazil, all the elevated tracts of land in America are comprised between the various ramifications of the mountain-chains which rise up in the far west in the vicinity of the Pacific. The plateau of Utah, or the "Great Basin," is a vast territory, the outline of which is of a bold character, and guarded by parallel ramparts of rocks; it is

bounded on one side by the foot of the Rocky Mountains, on the other by that of the Sierra-Nevada; it is the principal vertebra of the backbone of the continent.

Farther to the south extend the plateaux of New Mexico, Arizona, Chihuahua, and Sonora, all alike surrounded by mountains and intersected with ravines and valleys. The table-land of Anahuac, the enormous citadel which towers up between the two seas, is commanded by the peaks of Popocatepetl, Cofre de Perote, and Orizaba. Next, beyond the Isthmus of Tehuantepec, we meet with various small plateaux—those of Guatemala, Honduras, Salvador, and Costa Rica—which are all

Fig. 26.—Section of North America from the Mouth of the Columbia to Washington.



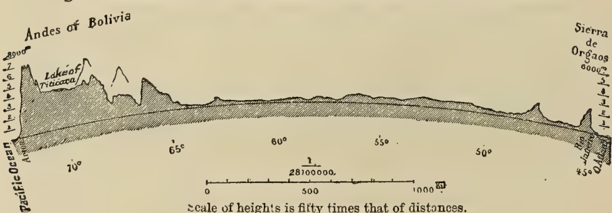
Scale of heights a hundredfold that of distances.

based on ranges of mountains partly volcanic. Their respective heights correspond in a general way with the greater or less width of their base, which is bathed on one side by the Pacific and on the other by the Carribean Sea.

On the south of the Gulf of Darien we have a series of high plateaux commencing with the enormous chain of the Andes. In every place where this lofty chain divides into two forks, or spreads out its ridges in a fan-like shape, it includes between the mountain-spurs a plateau of 4,500, 6,000, or sometimes even as much as 12,000 feet in altitude.

In Columbia we have the plateaux of Pasto, Antioquia, Cundinamarca, and Caraccas. Farther south, the two chains of the Andes and the Cordilleras, which

Fig. 27.—Section of South America from Arica to Rio de Janeiro.



Scale of heights is fifty times that of distances.

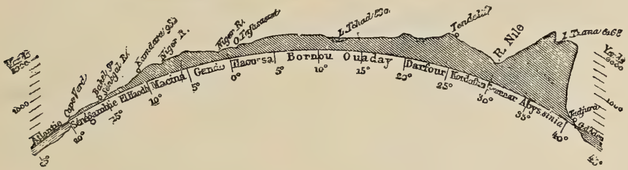
separate and then unite only to divide again, include between their snowy ridges the plateaux of Quito, Cerro-de-Pasco, Cuzco, and Titicaca, and lean laterally on the high desert tracts of Atacama, between Bolivia and Chili, also on the hilly terraces of Cuyo, westward of the Argentine *pampas*. Of all the South American plateaux, there is but one which is so completely shut in by the rising ground round it that it is unable to discharge its collection of rain-water into the plains below. This is the plateau of Titicaca; its mean elevation is not less than 13,200 feet, and, from its height and extent, it forms the most prominent feature in the profile of the Columbian continent. This Bolivian plateau is the counterpart of

the "Great Basin" of North America. These two corresponding regions both alike occupy the central portion of their respective continents, each being about 1,860 miles from the isthmus of Central America; they are also both situated between the forked extensions of a great system of mountains, and, in the depressions of their surface, contain lakes without any outlet to the sea.

Geographically speaking, these countries are as if isolated from the rest of the world. It is with great difficulty that the semi-barbarous inhabitants of Bolivia are able to enjoy any of the intercourse of commerce or civilization with the other American republics or the countries of Europe. The plateau of Utah is the spot where the Mormons have established their settlement in order to escape the pressure of their fellow-countrymen round them. A great display of North-American energy must indeed have been necessary for pursuing the youthful theocratic community into the deserts which protected them. The plateaux which witnessed the development of the autochthonous civilization of the Aztecs, the Toltecs, the Guatimaltecs, the Muyscas or Chibchas, and the Incas, have one immense advantage over the closed-up basins of Utah and Bolivia—they communicate freely with the sea-shore by means of their open valleys and the courses of their rivers.

The African plateaux are still more isolated from the rest of the world than the corresponding tracts of land in America; but it is not on account of their great height, or the perpendicular cliffs of the mountains which command them; the

Fig 28.—Section of Africa from Cape Verde to Tajura.



cause is rather to be attributed to the conditions of their climate and to the situation of the continent itself. The greater part of the elevated regions in Africa are but of comparatively low elevation, and their slopes afford an easy means of access. The plateaux of the Cape Colony, the mean height of which on the south is scarcely 660 feet, gradually rise towards the north up to the desert of Kalahari, at an elevation varying from 2,000 to 3,000 feet above the level of the sea. All that we at present know of the interior of Africa fully warrants us in thinking that the average height of the plateaux increases but very slightly as we approach the equator. In the very centre of the continent, the region of lakes, whence the Nile derives its source, does not present an elevation of more than 4,000 to 4,600 feet; also, in the north of Africa, the plateaux of Morocco and Algeria, along almost their whole extent, are below 3,000 feet in height. The most remarkable plateau on the continent is that of Ethiopia, over the entire extent of which —about 750 miles—a mean altitude is maintained of 7,000 to 8,000 feet. The steepest escarpments of this mass of land are turned towards the sea, as if to defend the Abyssinians from any attacks on the part of foreign nations. But the descent on the opposite or north-west side, in the direction of the Nile, is twenty times more gradual; and at this point Abyssinia would be easily accessible, if it were not that by the desert character of the country, the incessant conflict of tribe with tribe, and the miseries of the slave trade, any way of access to its frontiers is beset with perils.

CHAPTER XIX.

ISOLATED MOUNTAINS.—MOUNTAINS IN GROUPS.—CHAINS AND SYSTEMS OF MOUNTAINS.—THE BEAUTY OF MOUNTAIN PEAKS.—SACRED MOUNTAINS.—PLEASURES OF MOUNTAIN-CLIMBERS.

ALTHOUGH mountains do not play nearly so important a part as plateaux in the economy of the globe, they are, nevertheless, much better known, on account both of the majesty of their appearance and the sharp contrast which they present to the country round them, and also of the variety of the phenomena of which they are the scene of action. Mountains which tower up in solitary greatness either from the bosom of the sea or from some level plain, produce, more than all others, an effect of the highest grandeur, and make the most vivid and durable impression on the mind. The mind's eye can hardly picture scenes superior in beauty to those formed by the gracefully undulating slopes and purple summits of solitary mountains like the Ventoux, Etna, the volcano of Teneriffe, Orizaba, and so many other peaks, at the base of which a whole horizon seems spread out. Some of those heights which in mountainous countries would scarcely deserve to receive a name, and would be hardly looked upon as hills, make pretensions to be formidable peaks when they spring from the midst of a level plain or on the edge of the sea. This applies to a little hill of about 780 feet in height which stands in the centre of the monotonously level districts of Lower Pomerania; this hill has seemed so prodigious to the inhabitants of the country, on account of the savage wildness of its cliffs, that they have given it the name of the "Mountain of Hell" (*Höllenberg*). In the same way, a ridge in Denmark, which rises to about 557 feet in height above the level of the sea, has been called the "Mountain of Heaven" (*Himmelberg*); it is an Olympus, like that of Greece.

With the exception of volcanic cones, there are but very few solitary mountains which rise by themselves in the midst of a level country. In almost all the countries of the world—in those at least which at all possess a strongly-defined relief—we meet with summits in considerable number, either arranged in groups or in long ranges. Generally, those mountains which are grouped in the form of a circle surround a more elevated central summit, and are also themselves surrounded by heights of a secondary class, which abut upon lateral buttresses and gradually sink down to the level of the plain surrounding them. As instances of this sort, we may mention the group of the Hartz Mountains in Germany, Mount Ferrat in Piedmont, Sinai in the Arabian peninsula, the lofty cluster of the Sierra-Nevada of Santa Marta, which towers up to a height of 19,680 feet in an insular tract bounded

by the sea, the marshes, and the deep valleys of the Rio-Cesar and the Rancheria. The chains, properly so called, which are always distinguished by a considerable development of the length of the upheaved ground, sometimes also have a dominant peak as their central culmination, on each side of which the summits of the ridge become gradually lower; but there is no range where this regular disposition is carried out with anything like geometrical symmetry. The greater part of the mountainous upheavals are found to present a collection of clusters, chains, and subsidiary chains, variously grouped, in which a long process of study is required for duly ascertaining the direction of the ridges. They must not be looked upon as chains, but as systems, of mountains.

Owing to the diversified character exhibited by these numerous groups of heights, both in their geological origin, the composition of their rocks, the general direction of their axis, the position of their peaks, the vegetation which clothes them, the light which illumines them, and the atmospheric agents which waste them, every mountain is distinguished from its neighbours by certain characteristics of special beauty. From this very fact, among all this assemblage of summits, every peak, whether charming or magnificent, which rears its ravined sides above the base of upheaval, assumes an appearance of independent vitality, as if it enjoyed a distinct individuality. The sight of these giants towering up over a widespread horizon exercises a perfect fascination over the minds of some men, and they are urged by a kind of instinct, often quite unreflecting, to bend their steps towards the mountain, and to scale its acclivities. Through either the grace or majesty of their form, their bold profile standing out sharply against the clear sky, the girdle of clouds rolling round their rocks and their forests, and their incessant variations of light and shade gleaming through their ravines and recesses, mountains seem to assume an appearance of personality, and one is almost tempted to look upon their rocky masses as beings endowed with all the powers of vitality. Every mountain, the summit of which in its bold tracery stands out clear from the rest of the mass, seems to be so thoroughly an individual by itself, that in most cases a name has been given to it, often the half-poetic title of some hero or god; and, in everyday language, we constantly attribute to it even human qualities. Mountains, in fact, are truly enough geographical individualities, and, by the mere fact of their position in the midst of plains, they modify in a thousand ways the climates and all the other phenomena of the districts round them. Further, do they not exhibit within a limited space an epitome of all the beauties of the earth? Various degrees of climate and zones of vegetation are arranged in gradation on their slopes; there, too, we may embrace in one comprehensive glance the most diverse features of the earth's vitality—cultivation, meadows, forests, ice, and snow; there, at eventide, we may see the fading radiance of the sunlight illuming the lofty peaks, and endowing them with a marvellous effect of transparency, as if the enormous mass were but a rosy-coloured drapery floating lightly in the clear sky.

In days gone by the people used to worship mountains, or at least venerate them as the seats of their divinities. All round Meru, the proud throne of the gods of India, every stage of humanity may measure its progress by the side of other sacred mountains where the lords of heaven were wont to assemble, and where all the great mythological *épopées* of the life of nations have been brought to pass. The peak of Lofeu in China, and the volcano of Fusi-Yama in Japan, are both sacred mountains. The Samanala, or Adam's Peak, whence can be enjoyed a view full of grandeur over the well-wooded valleys of Ceylon, is also

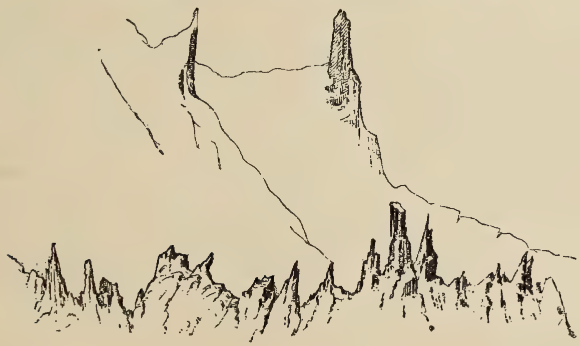
reverenced as a holy spot; and on its loftiest peak stands a wooden temple, fastened down to the granite mass by chains imbedded in the fissures of the rock. This, according to the Mahomedan and Jewish legend, is the spot on which Adam, driven out of the earthly paradise, came to do penance for many a long century; here, too, the divine Buddha left the mark of his footprint when he took flight to soar up into heaven. To the Armenians Mount Ararat is no less sacred than the Samanala is to the Buddhists, or the peak which towers over the sources of the Ganges is to the Hindus. It was on one of the rocks of the Caucasus that Prometheus was bound down in punishment for having stolen the fire of heaven. For many an age Mount Etna was the citadel of the Titans; the three brows of Olympus, which proudly rear their dome-like forms, were the magnificent dwelling-places of the gods of Greece, and when a poet wished to invoke Apollo, he turned his supplicating glance to the summit of Parnassus. If the polished Hellenes thus venerated the mountains of their native country, how great must be the adoration which would be paid by ignorant barbarians to the mountain which bore upon its terraced ledges their miserable huts, much as a forest-tree carries a bird's-nest on its spreading branches! The mountain which affords them shelter seems to them to reign far and wide over the earth, and in it they proudly recognise their father and their god.

In our day we have certainly ceased to worship mountains; but, at all events, those that know them best seem to love them with a perfect love. To scale the loftiest summits has at the present time become a complete passion; every year important ascents are made by thousands, independently of the minor expeditions which travellers undertake to the summits of a secondary class, and of easy access. Alpine Clubs, or societies of mountain-climbers, composed in great part of some of the most energetic and most intelligent *savants* of Western Europe, have devoted themselves to the task of vanquishing, one after another, every mountain-top which had been hitherto considered inaccessible; they carry away from them a stone as an emblem of their triumph, and they leave on them a thermometer, or other scientific instrument, in order to facilitate the investigations of any bold climber who may follow them. The Alpine Clubs have drawn up a list of all the peaks which are still rebellious, and have fully discussed the means of subduing them; they have also investigated multitudes of ascents, and, by their charts, their descriptions, and their numerous meetings, they have largely contributed in throwing light on the architecture of the Alps. The collected travelling journals of the members of these various clubs are unquestionably the source from which the most valuable information may be derived as to the rocks and glaciers of the loftiest mountains in Europe, and they also give us the most interesting narratives of difficult ascents. In the far distant future, when not only the Alps, but also all the other accessible summits in the world, have become perfectly familiar, the records of the Alpine Clubs will form the Iliad of mountain-climbers; and people will talk of the exploits of a Tyndall, a Tuckett, a Coaz, a Theobald, and of other heroes of this grand epic poem of Alpine conquest, just as the exploits of noted warriors were once the subjects of song. No mediæval knight ever displayed more zeal in the quest of the Saint-Graal, or of the Fountain of Rejuvenescence, than has been shown by these modern climbers to reach the formidable peak of the Cervin. Nor has this natural citadel surrendered without claiming its victims. No year passes in which some Alpine hero does not perish in similar attempts, and many more precious lives must fall before all the intricacies and summits of Mounts Rosa and Blanc have been thoroughly surveyed. Many peaks hitherto

accessible only to the soaring eagle have already been scaled; but others remain, such as the Aiguille du Géant, rising above Mount Mallet as abruptly as an Egyptian obelisk.

Whence proceeds the deep-seated joy which is felt in scaling a lofty summit? In the first place, there is a great physical pleasure in breathing the fresh keen air, which has never been vitiated by the impure emanations of the plains. Man feels renovated by merely tasting this atmosphere of life; the higher he mounts up, the more rarefied becomes the air; deeper inspirations are necessary to fill the lungs, the chest is swelled, the muscles are at full stretch, a cheerful flow of spirits pervades the mind. The pedestrian who scales a mountain feels himself his own master, and responsible for his own life; he is not delivered over to the capriciousness of the elements, like the navigator, who trusts his fortunes to the sea; much less is he like the railway traveller—a mere human package—paid for, ticketed, and put in a carriage, and then despatched at a fixed time, under the surveillance of employés in uniform. On alighting, he regains the use of his limbs and his liberty. His eye enables him to avoid the stones that lie in his path, to measure

Fig. 29.—Mount Mallet and the Aiguille du Géant.



the depths of precipices, and to discover the rocky projections and clefts which will facilitate the escalade of the cliffs. The force and elasticity of his muscles will enable him to leap safely over the deepest *crevasses*, to maintain his footing on the steepest inclines, and to raise himself, step by step, up the most difficult passages. On a thousand occasions during the ascent of a steep mountain he must fully recognise that he is running a fearful danger, should he either chance to lose his balance, or allow a sensation of giddiness to dim his sight, even for an instant, or should his limbs refuse their wonted service. This consciousness of peril, joined to the pleasurable knowledge of his activity and health, is the very sensation which, in the mind of the pedestrian, doubles his feeling of safety. With what joy does he afterwards relate the slightest incident of the ascent—the stones rolling down the mountain slope, and plunging into the torrent beneath with a deadened sound; the root to which he hung suspended when he scaled a wall of rock; the streamlet of snow-water at which he quenched his thirst; the first glacier *crevasse* over the brink of which he stooped, and yet dared to leap; the long and weary slope up which he so painfully climbed, with his legs buried knee-deep in the snow; finally,

the culminating peak from which he saw, spreading away into the mist of the horizon, the immense panorama of mountain, valley, and plain. When the traveller looks back from afar upon the summit which he conquered at the cost of so much exertion, it is with perfect rapture that he sees it again, or traces out with his glance the path that he followed, from the valleys at its base to its snow-clad peak. The mountain seems actually to look down and smile upon him from afar; for him alone its snow glitters, and the fading sunlight illumines it with his last ray.

CHAPTER XX.

VARIOUS FORMS OF MOUNTAINS.—POVERTY OF POLISHED LANGUAGES IN DESCRIBING THEIR APPEARANCE.—RICHNESS IN THIS RESPECT OF THE SPANISH LANGUAGE AND THE ALPINE AND PYRENEAN PATOIS.—THE NUMEROUS PROVINCIAL TERMS EMPLOYED FOR VARIOUS SHAPES OF HILLS AND MOUNTAINS.

MOUNTAINS vary singularly in their shapes, according to their height, their geological constitution, and the force and direction of the meteoric agencies that assail them. So vast is the multitude of causes, in great part unknown, which have laboured either in concert or in succession in carving out these projections of the earth, that every peak has its own special aspect. It would thus seem almost necessary to employ a particular designation, if not for every mountain, at least for each of the types to which we may be able to reduce the numerous shapes of the earth's protuberances. Unfortunately, our languages manifest a remarkable poverty in words well fitted to bring before the mind's eye the precise outlines of any particular summit. Whatever may be the appearance of two or more mountains, and the geological composition of their rocks, the geographer and the author are compelled to avail themselves of the same terms in designating them, unless, indeed, they have recourse to a long description in cases where a single word ought to suffice. They are, in fact, obliged to make use of words altogether unsuitable, such as the term "chain," which is invariably applied to ranges of hills.

The cause of this penury in exact geographical terms may be very easily understood. Most of the cities in which the various languages were gradually refined are situated on very level ground, or among hills very slightly undulated. There can be no doubt but that the French nomenclature in respect to mountains would have been much richer and more exact if, from Blois, Paris, and Orleans, lofty peaks had been visible in the horizon. The richness and the propriety of the terms employed by the southern Germans, the Spaniards, and Italians, when they wish to describe in one word various kinds of hills and mountains, are certainly derived from the fact that these nations have lived and formed their languages in full view of lofty summits. Humboldt, in his "Tableau de la Nature," quotes the following terms employed by Castilian authors—*pico, picacho, mogote, cucurucho, espigon, loma, tendida, mesa, panecillo, farallon, tablon, peña, peñon, peñasco, peñoleria, roca partida, laja, cerro, sierra, serrania, cordillera, monte, montaño, montañuela, altos, malpais, reventazon, bufa,* &c.—all of which serve to designate the diverse forms of mountains, or chains of mountains. It would be easy to still further enlarge this long list of names.

The inhabitants of the Pyrenees and French Alps use in their dialects a great variety of expressions, each of which is especially devoted to some particular type of mountain, and consequently serves to depict to the mind's eye a perfectly different form. Many of these names, inherited from the ancient Celtic and Iberian dialects, well deserve to be admitted into the French written language, the more so that they are in customary use by all the French mountaineers from the sources of the Rhone to the Pyrenees.

In the Alps of Queyras and Viso, lofty peaks with escarped sides which tower over all the neighbouring summits are known by the name of *bric* or *brec*. Of this kind is the beautiful pyramid-shaped mountain of Chambeyron (11,112 feet in height), which rises to the south of the valley of the Ubaye, in the midst of a circle of pointed summits of a less height. Of this kind, too, is the Viso itself, at least on its northern face, for the other side of the mountain presents too regular a slope to entitle it to the name of *bric*. Above the upper valley of the Guil, black cliffs rise up, furrowed by avalanches, then an enormous tower-like mass with perpendicular sides, and at last the truncated peak crowned with its thick covering of snow. The apparently inaccessible terrace which so proudly overtops the Col de

Fig. 30.—"Bric," or Crest, of Monte Viso, seen from the East; after Tuckett.

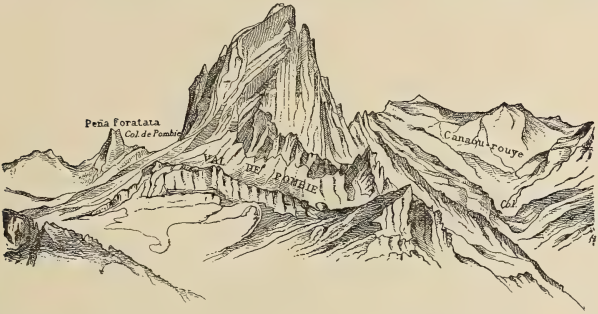
Valante, the secondary summits of Visoletto, and the rocks that have toppled down from the heights—this is the *bric* of the Viso. To any mountaineer who has never set eyes upon this proud summit, this term will convey far more meaning than the vague designation of "mountain." In the same way, the old term *pelve*, now disused, which, however, we may still recognise in the names of the Grand-Pelvoux, the Palavas, the Pelvas, the Pelvo, and several other mountains, in Dauphiné, at once depicted to the mind's eye an enormous cone commanding all the neighbouring summits.

The *tucs* and *trucs* of the Pyrenees are also summits of lofty elevation, but not the highest points in the ridge; they get this name on account of the bold outline of their upper cliffs, and not from their pre-eminence over the mountain-tops round them. As instances of these *tucs* we may cite those of Maupas, Montarqué, and Mauberme, in the Central Pyrenees.

The *tuque*, the *truque*, the *tusse*, and the *tausse*, all specify mountains with wider bases and more gentle slopes than those of the *tuc*; but nowadays these picturesque designations have been gradually displaced by the more general term of *pic*, which is applied without distinction to all pointed and almost inaccessible

summits. It is a curious fact that the downs on the Atlantic sea-coast, which by the inhabitants of the interminable level of the French *Landes* are looked upon as real mountains, still retain this provincial name of *tucs*, although it has fallen into disuse for the giants of the Pyrenees. A few miles from Arcachon, a down of about 260 feet high has made such an impression on the imagination of the

Fig. 31.—THE PIC DU MIDI D'OSSAU, SEEN FROM THE NORTH-EAST; AFTER V. PETIT.



inhabitants of the *Landes* that, by an emphatic pleonasm, they have styled it the *Truc de la Truque.*

Those very steep and pointed summits which are generally designated by the exaggerated but rather striking name of *aiguilles* (needles), have, in most cases, received from the natives of the district much less ambitious appellations, the most common of which is *pic*. The Pyrenees also include, among some of their highest mountains, several *piques*; as the Pique Longue du Vignemale (11,049 feet high) and the Pique d'Estats (10,104 feet high). The enormous cluster of the Alps of

Fig. 32.—EINSHORN DE SPLUGEN; AFTER COAZ.

Pelvoux has for its culminating summit a pointed peak 13,461 feet high, which was once called the *Barre des Ecrins*. But in Savoy and French Switzerland summits of this form are principally known by the name of *dent* (tooth), almost synonymous with the designation *horn*, which is used in Central Switzerland, starting from Mont Cervin, or the Matterhorn, that boldly modelled mass which Byron looked upon as his ideal type of a mountain. The *dents* are generally less pointed than the *aiguilles*, and are rounded off towards the summit; but the transitions presented by the mountain outlines are so gradual that it is difficult to

establish any very strict classification. In consequence great confusion prevails in the nomenclature, and the greater part of the summits in the Swiss Alps bear indiscriminately the name of *horn.* In the Tyrol, too, the term *kogel* (*kegel,* skittle) is applied to mountains of the most diversified shapes.

The four-sided pyramids which spring up so numerously in some mountain ridges are called the *caires, queyres, esquerras,* or *quairats* of the Alps and Pyrenees. Certain peaks of this kind have given a name to an entire cluster of the French

Fig. 33.—The Gross-Glockner; after Payer.

Alps—that of Queyras. If the point of the pyramid is replaced by an elongated ridge, the mountain-top then becomes a *taillante* (edge). If, on the contrary, the summit terminates in a cubical mass, it will be designated by the name *tour* (tower). Calcareous mountain regions are the localities where we chiefly find those enormous quadrangular layers, which seem as if they had been built up by the Titans. Few spectacles in Europe are equal in beauty to that afforded by a view from the Pic de Bergons over the limestone region of the central Pyrenees, with its perpendicular

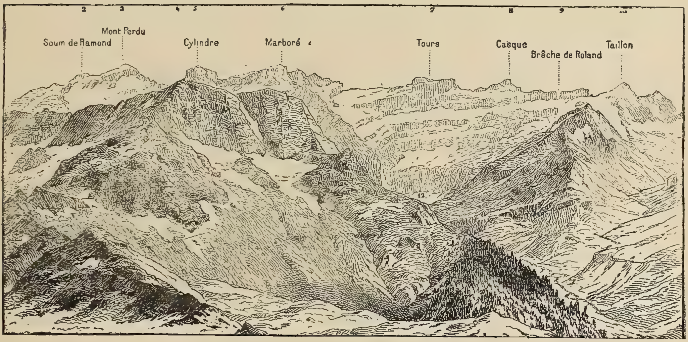
Fig. 34.—L'Esquerra des Eaux-Bonnes, seen from the South-west; after V. Petit.

walls, its snow-covered terraces, its tower-like heights, appearing to the glance almost inaccessible, and its carved-out gaps, like openings purposely made between battlements. A similar appearance is presented by the calcareous eminences of La Clape, near Narbonne, and by the sandstone mountains in several districts. The faces of these perpendicularly hewn peaks are often designated by the very appropriate names—*parois* (side-walls) or *pareds, murs* (walls), or *murailles* (ramparts).

Tower-like peaks of comparatively smaller dimensions, which appear as if they

were edifices lt on the mountain-tops, have received in the Pyrenees the name of *bène*, or *bougn*, perhaps synonymous with the Zurig term *buhn*. The *tête* (head) is a summit with regular and gently inclined terminal slopes, springing up from a mass furnished with steeper sides. If the roundness of the summit is developed in the form of a cupola, the mountain is then a *soum* (summit), or a *dôme*, as Mont Blanc, the giant of Europe. In German Switzerland mountains with flattened summits, as, for instance, the Rhigi, are known by the name of *kulm*. In the

Fig. 35.—The Gavarnie Highlands seen from the North; after F. Schrader.



Vosges the *ballons*, and in the Black Forest the *boelchen*, represent mountains terminating in large summits, which seem blown out in the shape of a bladder. The bases of these mountains are generally very wide, and the slopes gently inclined.

The names applied to summits of a secondary class are no less numerous than those given to the principal mountain-tops. A spur connected with a rounded summit frequently receives in the Pyrenees the appellation of *turon*, or *turonnet;* and an escarped projection, extending with saw-like indentations (*kamm*, in German),

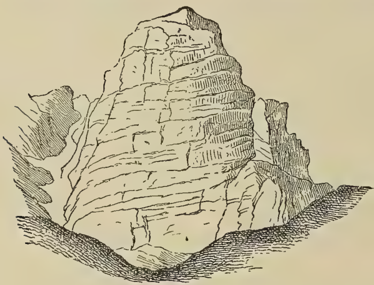
Fig. 36.—Pene: Piz a Lun de Guscha; after Coaz.

takes the name of *serre*, or some derivate of it, such as *sarrat*, or *serrère;* it is the Spanish *sierra* in miniature. A *motte* (*muotta* in the Grisons) is a mountain almost isolated from the rest of the group, or even rising in the midst of a valley in an alluvial district. Finally, some mountain names point out the nature of their rocks or their vegetation. The Lauzet or Lauzières mountains are composed of slaty rocks, and in the Pyrenees the numerous peaks called *estibère*, or *pradère*, are completely clothed with verdure. The words *puy*, *puig*, *pey*, *pech*, or *puch*, are

general terms which are applied indiscriminately to all the prominences either of mountain ridges or of the plain, from the Puig de Carlitte (9,563 feet high) down to the smallest elevations. It is remarkable that the words which, in the literary French language, are most used to denote elevations of the surface, namely, *montagne* (mountain) and *colline* (hill), are taken in quite a different acceptation in the idioms of the inhabitants of the Pyrenees and Alps. "*Montagne*" means only a greater or less extent of pasture-land, and the term "*colline*" applies to the dales lying between two mountains.

In addition to the names employed by the inhabitants of the Alps and Pyrenees to specify various types of mountains, we must mention some which are made use of in the French tropical colonies, one or two of which, such as *morne* and *piton*,

Fig. 37.—Tête: Wallenstock de Wolfenschiessen; after Coaz.



have found their way into literary language. In volcanic countries, the mountains of igneous origin, with summits rounded like a cupola, like the Puy-de-Dôme, or pierced with a crater like the Puy-de-Sancy, are almost all designated by local terms of very striking aptitude; but the greater part of these words remain unknown to fame. Nothing can prove more decisively how much modern communities still adopt as their ideal a life altogether artificial, and without sympathy with nature. Happily, a kind of reaction is steadily setting in. Attracted by the beauty of the summits which once startled them, crowds of travellers now find their way to the mountains; they learn to know them, to love them, and to describe them. Thus languages are enriched, and science gains a further store of information.

CHAPTER XXI.

INEQUALITIES AND DEPRESSIONS IN THE VERTICAL OUTLINE OF MOUNTAINS.—ORIGIN OF VALLEYS, GORGES, AND OTHER DEPRESSIONS.—LONGITUDINAL VALLEYS.—TRANSVERSE VALLEYS.—WINDING VALLEYS WITH PARALLEL SIDES.—VALLEYS WITH DEFILES AND GRADATIONS OF LEVELS.—CLUSES AND CAÑONS.—GENERAL ARRANGEMENT OF VALLEYS.—AMPHITHEATRES.—THE OULES OF THE PYRENEES.

MERE height constitutes the least considerable element in the beauty of mountains; the majesty as well as grace of their appearance is chiefly due to the distortions and dip of their strata, the circular dells and glens which are hollowed out upon their slopes, their yawning defiles, their abrupt precipices, and, finally, the broad valleys stretched out at the base of the colossus, which, by the contrast that they afford, enable us the better to appreciate the magnificence of its proportions. Owing to the variety of outline and scenery caused by all these successive depressions, the mountain has assumed an aspect of grandeur and life which it must originally have wanted. Like a block of marble transfigured by the sculptor's hand, the mighty mass, once a monotonous plateau or mere dome of rock, has been gradually modified by meteoric agents incessantly affecting it, and has been converted into one of those mountains in the proud profile of which our forefathers recognised the face of a god. We may easily figure to ourselves all the changes which have been affected in the form of mountains by the various depressions of the soil, if we visit certain groups of heights, one side of which retains its old plateau-like aspect, whilst the other, sinking abruptly towards the plain, has all the appearance of an actual escarpment. There are many instances of this kind in the region of the central plateau of France, of Auvergne, the Jura mountains, the Rauhe-Alp in Würtemberg, and in Bavaria. On one side stretch long stony slopes; the fields are all unfertile, and the prospect is uniform, and devoid both of movement and life. Then, all of a sudden, as we attain the edge of the ridge, we see opening out below us a succession of declivities: hollows filled with water appear between the escarpments and the fallen rocks; farther down, in the increasingly misty depths, we catch sight of terraces and ledges crowned with firs, and trickling rivulets glittering in the dells at the base of the cliffs. Far beneath our feet, at the very bottom of the gulf, lies the peaceful valley, like another world, with its winding river, its fields, its vineyards, its woods, and its busy towns.

What, then, is the origin of the valleys, gorges, ravines, and all the other depressions which we meet with in the elevated regions of the earth? This is a question which must be considered identical with an inquiry into the origin of the

mountains themselves, a point on which geologists are as yet very far from having come to any agreement. In the first place, however strange the statement may appear, it is certain that running waters are older than the mountains from which they flow. Wherever parallel ranges belong to different formations, as in the Andes and Himalayas, the rivers which descended from one slope before the upheaval of the next continue to make their way through the obstacles thus thrown across their course. According as the surface becomes modified, the streams still struggle to maintain their incline. To the work of upheaval thus corresponds that of erosion, and in this way in the course of ages the running waters pierce whole mountain ranges without changing their primitive level.

It may also be asserted, in a general way, that some of these depressions are primitive features of the ancient conformation of the mountains, and owe their origin either to disturbances of the strata or faults in the rocks; others have been gradually eaten away by time, or hollowed out by snow, ice, rain, and watercourses. Those who try to reconstruct in imagination mountain systems as they must have existed in preceding ages assert with certainty that some valleys were contemporaneous with the mountain groups which surround them. They also feel warranted in boldly declaring that this glen or that ravine was cut out by meteoric agencies; but, as regards a considerable number of the most important features of the mountain, doubt still continues to weigh upon their minds.

At all events, when extensive longitudinal valleys are included between two mountain-chains which are parallel to each other, but different in age and geological formation, these valleys are indisputably of primitive origin; they are the hollow of the terrestrial crust formed naturally by the slopes of the two acclivities which rise on the right and left. The whole length of the valley itself must have been upheaved by the forces which were at work on both sides of it under the adjacent masses, and it has also been variously modified during the lapse of ages by the watercourses which have traversed it. In one place its hollows have been filled up, in another its rocks have been carried away—the water having deepened it on one side to build it up on the other. But, notwithstanding all its modifications, the geologist none the less recognises the valley to have been furrowed out in the same age as that in which the neighbouring high mountain summits were formed. Thus the great depression of the lower Valais, which divides the peaks of the Finsteraarhorn and the Jungfrau from those of Monte Rosa and Mont Blanc, is certainly a primitive valley in all its essential features. For still stronger reasons, the vast cavity of the Lake of Geneva, which bends round between the Alps and the Jura Mountains, the lowest depths of which are but little above the level of the sea, must have had an existence at least coeval with all the mountains of Switzerland.

Certain transverse valleys, which break abruptly through a mountain-chain, and, as it were, cut it in two, must also belong—at least most of them—to the primitive mountain conformation. Of this kind is the charming valley of Engadine, the slope of which rises almost imperceptibly up to the foot of the Maloggia (5,941 feet), above which towers, 7,352 feet higher, the summit of the Bernina. In the New Zealand Alps, Julius Haast discovered a still more astonishing transverse valley, as the foot of it, commanded on both sides by peaks measuring 7,800 and 9,800 feet in height, was only at an altitude of 1,600 feet, scarcely one-fifth of the height of the chain. Finally, in all the mountain ranges composed of volcanic cones upheaved at intervals along the same fissure in the earth, large transverse valleys, which are in reality the remains of the former plain, are found

in great numbers. This may be especially remarked in Java and in the Chilian Andes.

Buffon has established the fact that a great many winding mountain-valleys are, from their origin to their outlet, walled in on each side by parallel escarpments. The projections on the cliff on one face correspond with the hollows on the other; the projecting and the re-entering angles alternate on either side, so that if the two opposite cliffs were suddenly brought close together, their windings and irregularities would mutually coincide. Other valleys, however, present an altogether different kind of formation: their sides, instead of running regularly in parallel curves, are in some places very wide apart, in others very close together. They thus follow a kind of rhythm very different to that of the first type of valley, and produce a succession of rounded basins, separated from each other by narrow passes. In the Pyrenees, the Jura, and the calcareous regions of the Alps, valleys of this kind are very numerous; but we more often observe a combination of the two modes of formation. At certain points of their course, valleys run tortuously between parallel sides; at others, they form successive basins. Thus the upper portion of the long channel of the Bosphorus, which may be looked upon as a valley, although now invaded by the waters of the sea, presents several stretches of water almost like lakes, whilst farther down the channel the indentations of the opposite banks are so regularly arranged that they might almost be fitted one into the other.

Fig. 38.—The Bosphorus.

The variations in the shape of valleys may be explained by the different natures of the rocks which the waters have had to hollow out. Wherever the materials operated upon —gravel, sandstone, granites, schists, or lavas—are of an analogous composition, and thus everywhere present an equal amount of resistance to the action of the water, the latter is able to pursue its normal movement, and adopts a meandering course, which approaches each bank in turn, thus communicating the windings of its bed to the valley it is hollowing out. On the contrary, when the rocks consist of strata of unequal hardness, or are traversed by obstructing walls, the water is necessarily compelled to spread out into a lake-like accumulation, in the meantime eating away the banks in a lateral direction, until— the barrier being at last penetrated—the sheet of water is poured down in a torrent to some lower level. In this way there has been formed, during a course of ages, a series of basins one above the other, some of which are still partially filled with water, others entirely empty, all being linked together by narrow

defiles, through which pours the mountain torrent. Instances of a series of this kind of small basins of verdure, arranged like a succession of steps, are very numerous in all mountainous regions. We may mention the valley of Oo in the Pyrenees, and in the Alps the lofty valley of Isère, in which old lake-basins and gloomy gorges alternate with great regularity.

The various channels or cuts which unite the various basins, and through which are precipitated the impetuous flood of the mountain torrent, are called in the Jura by the name of *cluses*, and in the Alps are designated as *clus*; but in these countries they do not limit themselves to cutting through mere barriers of rock, they pierce even through mountain chains. The basins of the Var and its watercourses are very rich in defiles of this kind—enormous incisions carried right through the thickness of the limestone ramparts. Among these *clus*, there are some which are really formidable—those of the Loup between Grasse and Nice, those of Saint-Auban and the Echaudan, and others which afford a passage to the waters of the Var and its tributaries. These are tremendous defiles; each side of the torrent is walled in with perpendicular or overhanging rocks, several hundred yards high, and the summit of the escarpment is generally crowned with the picturesque walls of some ancient village. These narrow gorges, through which it is often found difficult to carry a road or even a path, must be classed among the most curious sights in France. The view of these gloomy passes is all the more striking as one comes upon them immediately after travelling over the fertile plains of the Mediterranean shores, studded with villas, gardens, and olive-groves. The *clus* of the Aube and its tributaries, those of the Upper Dordogne, the Tarn, and the Lot are also formidable in their appearance; but the most remarkable in the world are probably the *cañons* of Mexico, Texas, and the Rocky Mountains, in which we see a river, almost without water, flowing at a depth of several thousand feet between perpendicular walls. According to Newberry, the geologist, the great *cañon* of the Colorado is not less than 298 miles in length, and in several places its perpendicular sides rise to a height of 3,300, 5,000, and 6,000 feet.

In accordance with the size of the mountains, the nature of their rocks, the abundance of their snow and rainfall, the elevated valleys exhibit the most astonishing diversity of shape and aspect. In clusters of mountains where the torrents rush down to the plain over a very steep bed, and through sharp windings hollowed out in the body of the rocks, most of the tributary valleys, opening right and left of the principal ravine, are constituted altogether like the latter, except perhaps that they are still more winding, and the water in them runs more rapidly; these, too, receive the streams of smaller glens which are still steeper than themselves. Generally speaking, every tributary vale unites with the central valley at the precise spot where the latter presents the convex side of its windings. The result is, that valleys and their tributaries as a whole exhibit an arrangement which is very similar to that of a tree with a succession of branches. In calcareous mountains, where the torrents run through a series of basins one above the other, and communicate by means of *cluses*, the system of valleys shows a more rudimentary arrangement. In this case, each basin is also the point of junction for two lateral valleys opposite to each other, and ascending in a straight line towards the heights of the mountain. The *ensemble* of all these symmetrical depressions reminds one of the trees in gardens which are trained as espaliers, the opposite branches of which creep along their supporters in parallel lines.

With regard to the dales, glens, ravines, and all the smaller depressions of a mountain, from those deep gashes which legends tell us were made by some giant's

sword, down to those gentle and graceful undulations which resemble the folds of drapery, their variety is so endless that it would be impossible to classify them in any systematic order. Each mountain, having its own peculiar individuality, differs in the character of its dales and glens, which, again, have each their special aspect of majesty or grace.

Almost every valley commences with a kind of amphitheatre of greater or less extent, hollowed out of the thickness of the central mass of the chain, and formed by the union of the ravines and gullies of the surrounding mountains. The amphitheatres of a circular or elliptical form, which we come upon all on a sudden, after having wandered along winding valleys or on the sides of perpendicular cliffs, form a beautiful spectacle in all their calm and peaceful grandeur. We must visit the calcareous mountain-chains, such as the Central Pyrenees, with their perpen-

Fig. 39.—Circular Valley of Ourdinse.

dicular walls and deeply hollowed basins, if we wish to see these wonderful amphitheatres in full perfection. The most remarkable, on account of their vast dimensions and the snow-clad terraces which surround them, are the *oules* (boilers) of Gavarnie, Estaubé, and Troumouse, which the slow action of centuries has hollowed out in the calcareous sides of the mountains of Marboré. Undulating tracts of pasture-land furrowed by torrents, prodigious walls rising to 1,500 or even 2,000 or 4,000 feet in almost perpendicular height, gigantic steps on which whole nations might find room to sit, cascades which either spread out over the precipice and float away in a diaphanous veil of mist, or rush down into the valley like an avalanche, the high summits, glittering with unstained snow, which rear their heads high above the walls of cliffs, as if to look over into the enclosure—all these features we find combined far in the recesses of these solitary mountains, so as to render the Pyrenean amphitheatre one of the grandest tableaux in Europe.

CHAPTER XXII.

DEPRESSIONS IN MOUNTAIN RIDGES.—DIVERSITY IN THE FORM OF PASSES (COLS). —RELATION BETWEEN THE RESPECTIVE ALTITUDES OF SUMMITS AND PASSES. —LAW OF DEBOUCHMENTS.—REAL AND IDEAL SLOPES OF MOUNTAINS.— ESTIMATED SOLID CONTENTS OF MOUNTAIN GROUPS.

MOUNTAIN necks or passes (*cols*)—that is, the hollows or depressions of the ridge of the summit, are, like the valleys, to be attributed to diverse causes; some are primitive features produced by the disturbance or rupture of the upheaved beds, others are excavations of more recent origin, and are due to meteoric action and the crumbling away of the mountain mass.

The variety of causes which have combined in the formation of these depressions sunk into the ridges, the varying force of resistance offered by different rocks, and all the events of the incessant conflict carried on for centuries between the mountain summits and the air which surrounds them, have combined in giving to these passes the greatest diversity of aspect. Some are mere turfy or snow-clad bands between two rounded brows, others are themselves narrow ridges of sharp-edged rocks, commanded on each side by pyramidal masses; these are the *fourches* (forks) and *hourquettes* of the Pyrenees. Others, again, are deep fissures carved out between perpendicular walls; some, even, like huge gateways opening between the valleys from opposite sides, are actual breaches, which we should be inclined to think had been effected in the living rock by the processes of sapping and mining. In the Pyrenees the depressions bear such names as *fourches, hourques* and *hourquettes*, corresponding to *forche, furche, furgge, forcole, forcolette, forcelle, forcellini, forclaz* in the Italian and Ramansch Alps, and to *émeindraz, coches, posterles, berches, baisses* in the Dauphiné.

It has often been asked if there is not a constant analogy between the altitude of summits and that of the passes which indent their ridges. It might easily be foreseen that, as the mountains had been diversely worn away by the effects of storms, snows, and water, the depressions of the passes, which are the result of these long-protracted erosions, must be looked for at various elevations in the different groups. This, too, has been proved by William Huber, as the result of patient comparative investigation. Thus, in the group of Mont Blanc, the proportion between the mean height of the summits and that of the passes is as 1·28 to 1; in the Monte Rosa group, it is as 1·43 to 1; in the Jungfrau, it is as 1·62 to 1. The relation between the highest summit and the lowest pass also differs very considerably in different systems of mountains. In the Todi group this proportion is as 2·68 to 1, but only as 1·53 to 1 in the Ticino Alps. In a

general way, the altitude of the widest and deepest passes of the Alps may be estimated at one-half of the height of the surrounding summits, whilst in the Pyrenees it is about two-thirds. The more considerable depressions which divide the Alps into distinct masses, towards which tend a quantity of secondary passes, give, by the contrast which they afford, a peculiar character of grandeur and variety to the orographic system of Central Europe. The Pyrenees are much more uniform than the Alps in their architecture, and, in consequence of the relative heights of their passes, form one of the most beautiful types of the *Cordillera* which can be found upon the earth.

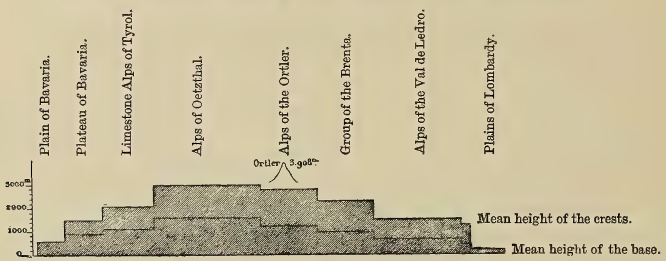
It is a remarkable fact, brought to light by Huber, that the passes which are hollowed out the most deeply in the mountain mass debouch precisely in front of the most elevated peaks of the opposite group. Thus the pass of the Simplon (6,594 feet) opens directly in front of the group of the Jungfrau (13,671 feet); and the Gemmi (7,161 feet), the least elevated pass in the Bernese Alps, debouches in the valley of the Rhone, directly in front of Monte Rosa (15,216 feet). In the same way, the pass of Lukmanier, (6,289 feet) faces the summit of Todi, and the pass of the Julier lies in the axis of the great Bernina group. It may, in fact, be noticed with regard to nearly all the principal passes that, on the other side of the valley, they are fronted by one of the highest mountains of the divergent chains which radiate round the central nucleus of the St. Gothard.

To what cause, then, are we to attribute this general situation of the principal passes, to which Huber has given the name of the "law of debouchments?" It may be explained in great part by the fact that the most elevated mountainous masses generally rest on the widest and most solid foundations; the torrents consequently pass round their bases, whilst on the opposite side the phenomenon of erosion becomes more active, and gorges are more and more hollowed out in the thickness of the chain. During the lapse of centuries, the differences in vertical outline between the escarpments of the two chains become very distinctly prominent. In the Pyrenees, this relation of summits and passes in two different mountain ridges can be pointed out only in a few instances, on account of the general simplicity of the chain and the comparative height of the passes. Nevertheless, here and there we find some unquestionable examples of this law; thus the entrance of Venasque opens exactly in front of the Maladetta, and the deep depression of the pass of Puy-Moren is opposite to the summits of the Fontargente group.

The comparative studies which have been made by various geographers, since Humboldt, as to the vertical outline of mountain-chains, have been directed not only to the comparative height of passes and summits, but also to the mean inclination of mountain sides. The real slope of a mountain ridge is, as is well known, the tortuous and variously inclined line which is followed by a streamlet of water in its descent from the ridge to the plain below; but it is not this more or less regular curve which is constituted the actual side of the chain. It is, in fact, an ideal line passing through the secondary summits and over the passes and dales, and connecting the summits of the principal ridge with the base of the incipient acclivities in the adjacent plains. This ideal line is never so much inclined to the horizon as the appearance of the slopes and the sudden contrast between the heights and the valleys would lead one to expect; painters, too, seem very naturally to exaggerate by one-third, or even by half, the real relief of a mountain outline, so as to give the effect which they truly enough produce on the eye of the spectator. On the French side, the Jura—the general incline of which is, however, very gentle—from the crest of Mont Tendre to the town of Arbois, presents a total

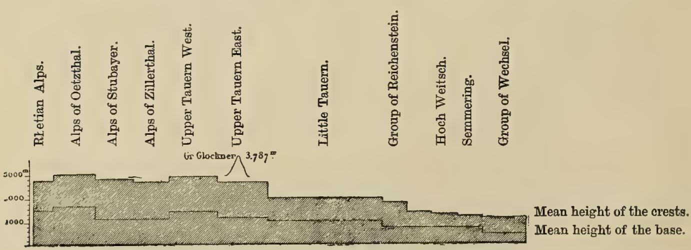
declivity of only 4,288 feet, that is, a gradient of about 2·6 in 100, which is but a moderate slope even for a coach road. The general inclination of the Pyrenees is much more rapid, since, from the summit of Mont Perdu to the plain of Tarbes —a distance of thirty-six miles as the crow flies—the declivity is 9,980 feet, or a gradient of 5·2 in 100. But even this is a much less rise than that of some of the high hills on mountain roads; it is also very inferior to that of the railroad which winds in zigzags up the sides of Mont Cenis. The most abruptly inclined moun-

Fig. 40.—Meridional Section of the Oetzthal Alps; after Sonkler.



tain side which can be found in Europe is that face of the Alps which is turned towards the plains of Piedmont and Lombardy; from the summit of Monte Rosa to the district of Ivrée, the mean slope exceeds 10 yards in 100, which to the eye produces the effect of an immense Babel of towers and pyramids placed one above another. Certain mountain groups in the New World have still steeper sides; thus the Silla of Caraccas turns towards the Caribbean Sea a real wall rising at an angle of 54° to the horizon; this would be a cliff of an all but inaccesible character, if it were not possible to scale it by zigzag paths through the gorges and ravines.

Fig. 41.—Section of the Austrian Alps along their Central Crest; after Sonkler.



It must, however, be understood that the declivity of mountain sides is not exactly the same in every part of the mountain groups; although very steep at one point, it may be tolerably slight at another, in accordance with the varieties of heights, rocks, and climates.

The mean declivity is difficult enough to ascertain, on account of the great diversity of slope in different places; but the total volume of a chain of mountains is a much more difficult thing still to find out, even approximately. Humboldt, taking as his basis the scientific data (which are still too incomplete) as to the

heights of plateaux and mountains in various continents, has endeavoured to estimate the cubical mass of several great mountain chains. According to his calculations, the total mass of the Pyrenees, spread uniformly over the whole surface of France, would raise the soil only about 10 feet. In like manner, if all the materials of the Alpine masses were equally distributed over the continent of Europe, they would augment its height only about 21½ feet. It would be very useful to renew these investigations, so as to arrive at results which would be more and more exact, as the orographical outline becomes better known. The most perfect calculation of this kind which has ever been made is probably that of Sonklar as to a portion of the Tyrolese Alps known under the name of the Oetzthal group. This mass would be represented by a solid body, having a uniform height of 8,333 feet, of which 5,314 feet would be for the plateau or pedestal of the mountainous region, and 3,019 feet would be for the whole of the peaks. This mass, if spread over the whole of Europe, would represent an increase of only 2 feet in the height of the continent. We thus perceive that as regards the question of bulk, mountain-chains are much less important than plateaux like Spain or Bavaria.

CHAPTER XXIII.

HYPOTHESES AS TO THE GENERAL LAWS OF MOUNTAIN-CHAINS.—M. ELIE DE BEAUMONT'S THEORY OF PARALLEL UPHEAVALS.—CHAIN OF THE PYRENEES TAKEN AS A TYPE OF THE CORDILLERAS OR LONGITUDINAL CHAIN.—VARIOUS IRREGULARITIES IN THE CHAIN.—THE PYRENEES AS AN ETHNOLOGICAL BARRIER.

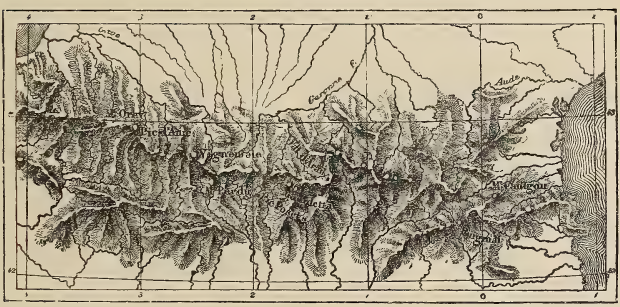
SEVERAL geographers have fancied that they had discovered the law of the general arrangement of mountains, and, without so much as waiting until the whole surface of the earth became thoroughly known, have traced out, according to their own notions, ranges of mountains more or less hypothetical. Thus, Buache, whose ideas were very prevalent for a long time, imagined that the chain of the Pyrenees was prolonged underneath the Atlantic, then across the New World and the Pacific, and after making its appearance in Asia, and forming in succession the Himalaya, the Caucasus, the Balkans, the Alps, and the Cévennes, finally returned to the point it started from. It was, in fact, the ancient image of the mythical serpent coiling itself round the globe and biting its own tail. We have only to glance at the maps which, at the present day, science enables us to trace out, in order to see how completely primitive this idea was as regards the harmony of the terrestrial configuration. It is, on the contrary, by a singular variety of phenomena that the laws of nature are always revealed.

Of course it may be said, in a very general way, that the principal chains of mountains, interrupted here and there by gulfs, arms of the sea, or plains, form a kind of great circular rim round the double basin of the Indian Ocean and the Pacific. In like manner, it is certain that the mean altitude of the elevations of the ground, both mountains and plateaux, gradually diminishes as we leave the tropical regions and approach the poles. But how numerous are the exceptions which come under our notice when we study the endless variety of the geographical relief of the earth's surface! Some countries seem a perfect labyrinth of plains, plateaux, and mountains, of every shape, form, and height. In one place we find granite peaks and domes of porphyry; in another, ridges of schists cut up into needlelike points; limestone ramparts and basaltic cones of almost mathematical regularity of outline. This is due to the fact that the series of mountains which have been elevated during each period of the earth's existence have been added to by successive series of subsequent upheavals. Whatever the first rule may have been, it has gone through an incessant process of modification during the lapse of ages.

It becomes, therefore, the function of geology to decide as to the real order of

arrangement of mountains, by describing the history of their formation. M. Elie de Beaumont has endeavoured to fulfil this great task, and, by a bold generalization of scientific facts, has succeeded in drawing up a theory of great simplicity. Taking as his starting-point the fact that the steeply-inclined sedimentary strata which stretch along the side of a mountain must necessarily have been upheaved, whilst the strata which have remained horizontal have not been disturbed since their formation, the eminent geologist has thus been enabled to assign a relative age to each system of mountain-chains. In fact, every chain which presents on its slopes the vertical beds of any geological formation, and at the base of which we find the strata of a later age, must evidently have been upheaved from the surface during the longer or shorter interval which separated the formations of the two series of strata. Now, if we compare the directions of mountain systems of the same age, we find that they are nearly parallel in the set of their ridges. M. Elie de Beaumont has, therefore, classified various mountain-chains according to their direction, and has in this way pointed out some very remarkable coincidences between ridges of upheaval separated from each other by thousands of miles. One most important fact which results from this classification of mountains is, that the most ancient

Fig. 42.—The Pyrenees.



systems are generally the least elevated. The Vosges date from a much more remote epoch than the Pyrenean chain; the latter was uplifted before the Alps, which also belong to an age much anterior to that of the Andes.

Among the mountain-chains which assume an almost perfect regularity, we may mention the western portion of the Pyrenees. Just as a branch of a tree, or better still, a stalk of fern, is divided and subdivided right and left into small branches, leaves, and leaflets, so every *knot* in the ridge gives rise on both sides to transverse chains, similar in every respect to the mother-chain, except that they are much shorter and sink by successive falls down to the level of the adjacent plains. The transverse chains are also parallel, and separated from each other by deep valleys, down which glaciers rush, torrents roar, or footpaths wind. The valleys on each side of the principal chain correspond closely and communicate with each other by a *col*, *port*, or *passage*, that is, a depression opening between two summits. Like the principal ridge, each subsidiary transverse chain is also composed of a succession of summits, separated from each other by passes, the height of which proportionately diminishes. Each summit gives rise to two lateral spurs, which are, in fact, nothing but the rudiments of a tertiary chain running parallel to

the principal one; the secondary passes, too, serve to connect short ravines which empty their streams into the torrent of the principal valley.

The portion of the great Pyrenean chain which is comprised between the pass of Roncevaux on the west, and the *port* of Venasque on the east, may therefore be considered as the perfect type of a regular ridge of mountains. The eastern portion of the chain is not arranged in so orderly a way: an examination of the lines of the ridge will prove that at several points it departs from the typical form.

The principal irregularity is to be found at about the centre of the chain, at an almost equal distance from both seas. We may there notice that the Pyrenean chain is not of a simple configuration; but that, on the contrary, it is formed of two distinct lines, one of which is a continuation of the regular western chain; whilst the other, divided into three parts by the Col de la Perche and the Col de Puymoren, commences on the shores of the Mediterranean, under the name of the chain of the Albères; at the Costabona group it crosses the more important trans-

Fig. 43.—Lateral Ridge between the Valley of Luchon and the Val d'Aran; after V. Petit.

verse ridge of the mountains of Cadiz and Canigou, and tending towards the east forms the clumps of Andorre, Montcalm, and Mont Vallier; then running parallel to the chain coming from the Atlantic, it terminates on the right bank of the newly-born Garonne. The Pyrenees may be compared to a regular chain which has been divided into two by some gigantic fault, the two halves of which, remaining fixed at each of their sea-coast extremities, have turned slightly and in contrary directions round these extremities, as if on pivots.

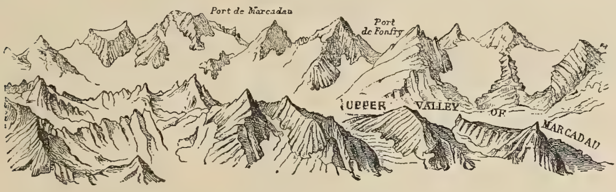
A transverse ridge, abutting at right angles to the northern chain, but encircled on all sides by steppe lands, where rise the tributaries of the Garonne and the Noguera Pallaresa, project towards the lacustrine hills skirting the Aran Valley on the south-east. This is the Piedrafitta group, whose very name was till recently unknown, although its peaks attain elevations of 8,300 and even 9,000 feet. Forming a parting-line between the Mediteranean and Atlantic systems, this group forms the true centre of the Pyrenees. Its waters flow on the one side through the Garonne down to the plains of France, on the other through the

Noguera to the Iberian peninsula, although it belongs orographically to neither of these basins. With a greater show of reason than the valley of Andorre, the district of Aran might have remained as a neutral republic between France and Spain, the two adjacent states.

A second anomaly may be found in the fact that the highest summits are not situated on the principal ridge. Thus, Mont Perdu, the Posets Peak, and the Maladetta, rise to the south of the Atlantic chain of the Pyrenees; the first of these mountains is connected with the central axis by several elevated passes; but the peaks of the Posets and the Maladetta, giants which front each other on each side of the Essera, form two almost completely isolated groups. On the north side only, some snow-clad ridges link them on to the principal system.

Nevertheless, in spite of all these irregularities, resulting from the incessant labour of the agents which are at work in modifying the surface of the globe, the chain of the Pyrenees must ever be considered as an instance of a regular system of mountains, and among all the ranges on the face of the earth but very few can even be compared with it in the regular simplicity of its formation. The aspect of the Pyrenees is therefore less diversified than that of the Alps and of several other mountain systems. The long range bounds the horizon with a uniform wall,

Fig. 44.—The Sierra de Marcadau, viewed from the Pic du Midi from the North-east; after V. Petit.



indented with points like the edge of a saw (*sierra*), and, looked at from the plain, its subsidiary spurs are scarcely visible, Although the mean height of the central ridge of the Pyrenees exceeds that of the Alps by about 300 feet, and the plains of France are lower than those of Switzerland, yet this superior comparative elevation produces less effect on the spectator on account of the regular arrangement of the peaks and the similarity of their outlines. Few, if any, summits in the Pyrenees exceed by more than 2,000 or 2,500 feet the mean height of the ridge (8,037 feet); whilst in the Alps many of the mountains rise more than 6,600 and 8,250 feet above the mean height of the range, and Mont Blanc rears its terminal point to an elevation of more than 15,700 feet. The mountains of the Pyrenees more generally assume the form of mere cones rising from the upheaved base. Some mountains, too, of considerable geological importance, as Néouvielle and the mountains of Oo and Clarabide, are scarcely to be distinguished by their vertical outline from the heights which surround them. Peaks which are plainly disconnected from the rest of the chain—such as the Canigou, Mont Vallier, the Pic de Tabe, the Pic du Midi at Pau, and the Maladetta—are not very numerous.

In consequence of the simplicity of configuration which prevails in the Pyrenean chain, we find in these mountains but few of those longitudinal valleys rising up to the right and left towards two parallel ranges of peaks, and pushing their arms of verdure into all the gorges and even to the moraines of the glaciers. In these

mountains we see nothing but valleys, which cross the axis of the ridge, and are steeply inclined down towards the plain. The passes where the incipient ravines of these valleys take their rise are often mere plateaux on the summit of the ridge, or else dark gorges hollowed out in the rock by the long-protracted labour of various atmospheric agencies. These passes are also more elevated on the average than those of the Central Alps. It is therefore easy to understand why it is that, among all the natural ramparts in Europe, the Central Pyrenees have always been the most insurmountable barrier of nations. Between the Col de la Perche, near Montlouis, and the port of Maya, not far from Bayonne, a distance of more than 180 miles, the chain of the Pyrenees is not crossed by any carriage-road.


Strasbourg
Rhine
Danube
Bâle
Berne
Geneva
Saone
Doubs
Meuse
Moselle
Marne
Aar
Mt Blanc
Mt Rosa
Mt Cenis
TURIN
Po
Mt Viso
Genoa
GULF OF GENOA
Rhine
Mt Ortler
Mt Bernina


Augsbourg
MUNICH
Inn
Danube
VIENNA
G. Glockner
Drave
Save
Trieste
VENICE
ADRIATIC
Adige
Po
FLORENCE
9
10
11
12
13
14
48
47
46
45
44
100

CHAPTER XXIV.

MOUNTAINS OF CENTRAL EUROPE.—CONTRAST BETWEEN THE ALPS AND THE JURA.—THE JURA AS A TYPE OF A SYSTEM OF MOUNTAINS WITH PARALLEL CHAINS.—APPARENT CHAOS OF THE ALPS.—CENTRAL GROUP OF ST. GOTHARD. —GROUPS OF MONTE ROSA AND MONT BLANC.—THE ALPS CONSIDERED AS A FRONTIER.

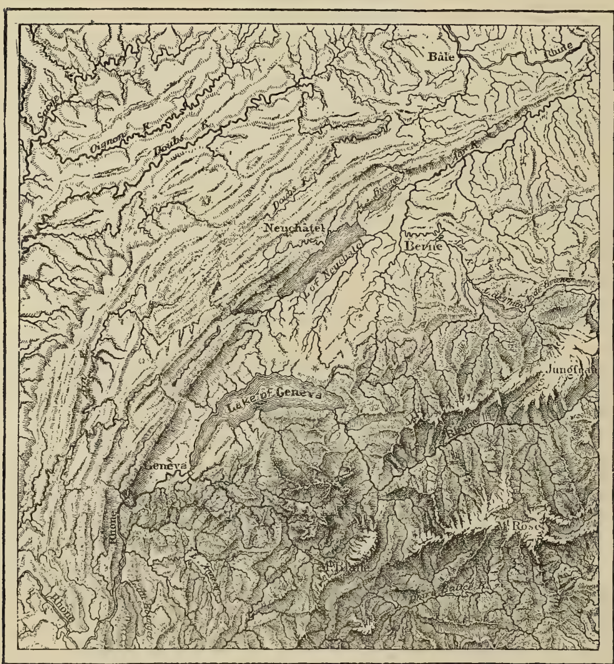
THE great system of mountains which forms, as it were, the backbone of Europe, and the ramifications of which, like the limbs of a body, determine the very shape of the continent itself, is very different from the Pyrenees in the richness and variety of its configuration, the intersection of its ridges, the number of its more isolated groups, and its framework of secondary chains. To the vertical outline and distribution of the Alps, the glaciers of which supply whilst they moderate the watercourses of Western Europe, the nations which inhabit the latter country owe, indirectly, much of their vitality and civilization. Standing up like the bastions of a fortification, the chief Alpine groups form a protection to the brave Swiss people. On the south, the *ensemble* of all the mountain groups sweeps in a vast semicircle round Northern Italy, and is linked on to the chain of the Apennines, which constitute the backbone of the peninsula; on the west, the spurs of the Alps form the most prominent feature of the French territory, and by their transverse chains modify the relief of the Jura; on the north, the gradation of plateaux, which abut on the mountains of Switzerland, descend as far as the *landes* of Prussia; finally, to the east, the Carnic Alps extend into Bosnia and Servia in calcareous ranges and plateaux, which are divided only by the Danube from the Transylvanian citadel of the Carpathians, and which, through the Balkans and the Pindus Mountains, radiate out to the shores of the Black Sea and the Ægean.

The singular beauty of the Alps is still further enhanced by the contrast which they present to the mountains which surround them. The contrast is especially remarkable between the groups of the Central Alps and the ramparts of the Jura which form the western boundary of the natural territory of Switzerland. The chains of the Jura, more unpretending in height in comparison with those of the Alps, are nevertheless very curious in a geological point of view, and must be looked upon as the best type of one particular formation of mountains—that of long parallel ridges. Carniola, Herzegovina, and Bosnia, also possess chains arranged in a similar manner. In America, too, we might point out the Ozark Mountains, and especially the Alleghanies, which extend over a still more considerable area than the Jura; but they have been much less studied. They are, besides, connected on both sides with granitic mountains, and the principal mass

of the system, which is often compared to long waves of the sea, is complicated with numerous irregularities.

The European Jura occupies a very considerable area in the middle of the continent, from the banks of the Drôme to the mountains of Bohemia. The central portion of this immense tract of land is all that is commonly understood under the name of Jura; for the more extreme points are very variously inflected and intersected by masses of distinct formations. Thus, in Savoy, the Môle and other peaks stand at the angles where the walls of the Jura intersect the Alpine chains. The Jura, properly so-called, extends from the south-west to the north-

Fig. 45.—The Jura.



east, from the valley of the Rhone to that of the Rhine, presenting a slight convexity towards France. It consists of parallel and almost uniform ranges, which rise in successive gradations, tending from the west to the east. These ranges are like so many walls, with sloping declivities on one side, and terminating on the other in abrupt escarpments. Intermediate valleys separate these parallel walls, the most eastward of which is by far the most elevated, and commands, in all its height, the plains of Switzerland. Hollows or *combes*, in the form of an amphitheatre, open out in the thickness of the Jura ramparts, and here and there *cluses*, or transverse defiles, enlivened by torrents, cut right through the chains and divide them into isolated fragments. These fragmentary plateaux, which, in

their extensions follow uniformly the same direction, have been often compared to those species of caterpillars which creep along the ground in long processions. If we take no notice of the cluses which divide the walls of the Jura into so many bits, we may more poetically compare these mountains to the ripples produced by throwing a stone upon some liquid surface.

The elongated brows of Mont Tendre, of Mont Noir, and the Weissenstein, form magnificent observatories, from which one can study at ease the marked contrast between the Jura and the groups of the Oberland, bristling with its pointed summits, to the east of the Bernese depression. At first sight, these mountains seem to form a veritable chaos; but this chaos appears much greater still when seen from one of the lofty summits of the Alps themselves. We then perceive, round the whole line of the horizon, points, pinnacles, and ridges, thrown together as if by chance, and almost innumerable; they might well be called the congealed waves of an immense ocean. Very different from the Jura, the general formation of which is so striking in its regularity, the Alps appear to be nothing but a dreadful accumulation of disorder, and only a long course of study or personal survey will enable any one to become acquainted with the general arrangement of their ridges. It may then be seen that the *ensemble* of these mountains is formed by separate groups throwing out branches in every direction, like the rays of a star. Whilst the Jura, and the systems of mountains belonging to the same type, are composed of parallel chains, the Alps are constituted by the juxtaposition of many groups with divergent chains radiating from them.

M. Desor, taking as the basis of his classification of the Alps the various *nuclei* of granite and protogene which have pierced through the more recent rocks, has come to the conclusion that the Alpine system is composed of fifty distinct groups. This entirely geological division harmonizes in general with the results of a mere study of the vertical outline and direction of the ridges; but the number of groups must be considerably reduced, if those which are linked to one another by continuous ridges of great elevation are looked upon as forming parts of the same chain.

The central mass, which is also the most important in a geographical point of view, is that of the St. Gothard, situated between Switzerland and Italy, at the summit-level of the waters of the Rhine, the Ticino, the Rhone, the Aar, and the Reuss; it is the knot or focus where the convergent ridges of the surrounding groups unite like *radii*. On the north-east stands the group of Tödi; on the east, that of Rheinwald; on the west and south, the much more considerable clusters of the Finsteraarhorn and Monte Rosa. The latter group is linked on to Mont Blanc, rising more to the west; but at this point the Alpine system changes its direction, and, as a whole, bends round towards the South. The two first of the more important groups which rise on this side are those of the Grand-Paradis, commanding the plains of Piedmont, and that of the Vanoise and Grande Casse, dividing the Tarentese and Maurian valleys. A real chain bends round to the south, which is crossed by the Mont Cenis road; the winding ridges of these chains go on to join the groups of the Grandes Rousses, and Belledonne on the west, that of the Grand Pelvoux on the south-west, and that of Monte Viso towards the south. The pyramid of Monte Viso is the magnificent boundary-stone which marks out the line of demarcation between the Alps of Dauphiny and the Maritime Alps; it is also the last mountain in the chain the height of which exceeds 11,500 feet. Beyond this point, the terminal branches of France and Italy spread out like the leaves of a fan, gradually sinking down towards the sea

To the north of Nice and Mentone, a small granite group rises to a height of more than 9,900 feet, and two of its highest summits, the Gelas and the Clapier de Pagarin, have small glaciers on their northern slopes. At this point the great curve of the Western Alps comes to a termination, and the intermediate chain commences which unites the former to the ridge of the Apennines.

The Eastern Alps, situated to the east of the St. Gothard, also assume a similar arrangement in groups. On the north-east of the Tödi stands the Säntis; to the east of the Rheinwald are the groups of the Bernina, Silvretta, and the Ortelspitze; then follow, tending from west to east, the groups of the Oetzthal, the Stubaier,

Fig. 46.—Valleys, Gorges, and Combes of the Jura.

the Gross-Glockner, and the mountains of Hallstadt, beyond which the Alps proper lose their primary importance. The summits of all these groups are more than 9,900 feet in height, and are clad with snow; like the western chains, they well deserve the name of Alps (white) which the Celts gave to these mountains.

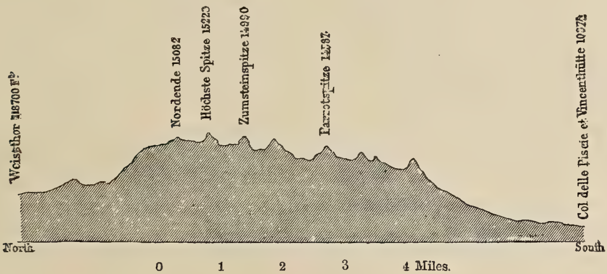
Most of these Alpine groups exhibit a singular diversity of aspect, in all the various details of their relief. There is no feature in this mighty architecture which is devoid of its own special characteristics of beauty, and also there is no beauty which is not, by some unlooked-for contrast, individualised in each mountain.

In the first place, the central group of the St. Gothard, the knot from which

radiate all the principal chains, is not very lofty, and is, in fact, of an altogether secondary class, in comparison with the other Alpine groups. It is a quadrilateral mass, surrounded on all sides by deep valleys and the wide depressions of several passes—on the west, the Furka, on the north the Oberalp, on the east the Lukmanier, on the south the Nufenen—and is crowned by summits, the mean height of which attains 9,678 feet, the most important, the Piz Rotondo, not exceeding 10,488 feet in altitude. It is probable that, during the long course of ages, the upper waters of the Rhine, the Rhone, the Reuss, the Ticino, and the Toccia have had the effect of lowering the mountains of St. Gothard somewhat below the surrounding summits.

Another anomaly in the Alpine system is the fact that the mean elevation of the snowy groups which rise east and west of the St. Gothard is not in direct proportion to the heights of their crowning summits. In fact, the true citadel of the Alps—that which, by the form of its mountains, the number of its peaks, and the importance of its glaciers, deserves more than any other the title of the culminating group—is the mighty bastioned rampart of Monte Rosa, the mean height of which is not less than 13,457 feet. The supreme diadem of this association of

Fig. 47.—Profile of Monte Rosa.



mountains is at a height of 15,216 feet, whilst Mont Blanc rises to 15,780 feet; but the group of summits which surround this highest point of Europe is only 12,657 feet in mean altitude, 800 feet less than the heights of Monte Rosa. Next follow in order of elevation the groups of the Jungfrau, 12,312 feet; the Bernina, 11,345 feet; the Grison Alps, 10,583 feet; and the Tödi, 10,311 feet. Taken as a whole, the various groups of the central Alps decrease in height from west to east, and from south to north; their southern slope is uniformly more abrupt than the northern declivities, which descend in long branches towards the valleys of the Rhone and the Rhine.

Considered in their *ensemble*, the Alps, like most mountains, serve as chains, ethnological frontiers, on one side to the French and Germans, and on the other to the inhabitants of Italy. The district of the Grisons, one of the most inaccessible of all the Alpine regions, which by the labyrinth of its five hundred valleys has been converted into the central citadel of Europe, served as a refuge to the Rhetian peoples, who still speak, though in a corrupted form, the language of their ancestors, the contemporaries of the citizens of ancient Rome. The Alps, however, owing to their divisions into numerous groups and to the comparative lowness of their passes, do not constitute an insurmountable barrier like the chain of the

Pyrenees. On the mountains and in the valleys of Switzerland, men belonging to three races—German, French, and Italian—are confederated so as to form a nation of brethren. German colonies, surrounded on all sides by a Latin population, have established themselves on the mountain-sides facing the north; for instance, in the Viége valley and in the *Sette Communi* in the environs of Bassano. Added to this, men of the Latin race have colonized the southern slopes of the groups inhabited principally by Germans; finally, the ancient *Allobroges*, all alike nowadays speaking more or less impure French, inhabit the two sides of the Alps of Savoy and Dauphiny. Whilst, in the Pyrenees, the *ridge* of the mountains distinctly separates the two nations of France and Spain, it is, on the contrary, the *bases* of the Piedmontese mountains which serve as frontiers, if not political, at least ethnographical, between two races. The valleys of the Italian side, traversed by the streams of the two Doires, the Cluson, the Pellis, and the Stura, have a population of the same stock as the valleys of Maurienne, Queyras, and Durance. Besides, as Ami Boué, the geologist, long ago pointed out, longitudinal chains are those which form the least separation between peoples, owing to the resemblance of the climate on the two slopes; transversal chains, like the Pyrenees, are always the frontiers which are the most difficult to cross.

For all the interchanges of commerce, as well as for the mutual intercourse of peoples, the Alpine groups are also much more happily arranged than the regular chain of the Pyrenees; and the traffic between the two opposite sides has always assumed a very considerable importance. Twelve carriage roads, some of which may be reckoned among the *chefs-d'œuvre* of human industry, cross the ridges of the Alps, and form the means of communication between France, Switzerland, and Germany. A railway also, now some years finished, passes to the east of the Greater Alps through the Soemmering chain, while three other railway lines have already pushed their way into the depths of the lofty central and western mountains, so that free communication has now been established under the rocks and glaciers, and we are able to make the boast that we have levelled the Alps.

CHAPTER XXV.

MOUNTAIN-CHAINS OF CENTRAL ASIA.—THE KUEN-LUN, THE KARAKORUM, THE HIMALAYA.—THE SOUTH AMERICAN ANDES, A TYPE OF THE BIFURCATED CHAIN.

THE chains of the Himalaya, the Karakorum, and the Kuen-Lun, fill the same position in the continent of Asia as that occupied by the Alps in Europe. These three ranges of mountains have a common origin in the plateau of Pamir—the "Roof of the World"—from which other ranges also radiate towards the north and west. The triple rampart of Upper Asia is not less than 1,550 miles in linear development, and its breadth, including that of the plateaux and intermediate valleys, is, towards the east—that is, towards Sikkim—about 620 miles. In each of the three chains the mean altitude of the summits exceeds that of any other ridge of mountains in the rest of the world; this spot is, in fact, the culminating point of the earth. Between the two extreme sides the contrast is most decided. On the north, cold and arid steppes stretch away over an immense extent; on the south lie spread out the burning and wonderfully fertile plains which are watered by the Ganges and its tributaries. The rocky and snowy ridges which tower up between the two regions form an ethnological barrier more mighty than the ocean itself; they divide races of men and great systems of religion. There are but very few points at which the Buddhist Mongols—thanks to the greater facilities which were afforded them, by their residence on the high plateaux, for crossing the mountains—have made their way down into the southern valleys of the Himalaya.

The northern chain, that of the Kuen-Lun, is very little known, and it cannot as yet be stated positively whether it may not contain some summits more elevated even than those of the Himalaya. It is, however, probable, from the information that has been acquired by travellers as to various points, that the ridge of the Kuen-Lun is the least lofty of the three. The Karakorum, which is the middle rampart, is also that of which the mean height is the most considerable; and in its gorges the Indus and the Brahmaputra take their rise. At its base lies the valley of Cashmere, which the Oriental poets celebrate as the "abode of happiness;" its lovely blue lakes, surrounded with gardens, reflect the snowy peaks of fifteen or eighteen thousand feet in height. The torrents which flow from both sides of the mountains cross the parallel chains through prodigious defiles, which in some places reach a depth of thousands of feet.

The Himalaya, the best known of the three chains, has, however, been but slightly explored in comparison with the European Alps. It is protected against all the attempts of explorers by the want of roads or even paths, by its impetuously

rushing streams, entirely unbridged, by the inaccessible forests of its slopes; by its formidable cliffs, and the height of its lofty summits, piercing through the clouds into the attenuated air, where man can scarcely draw his breath. On the face of the mountains a zone of variable width extends, like a barrier of death. This is the Teraï, the unwholesome dampness of which, fostered by the rains of the monsoons and the water descending from the Himalaya, steams in the sun in long-drawn-out mists creeping over the trees, and spreads, far and wide, fevers and pestilence. Finally, several of the mountain districts still belong to native sovereigns, who oppose, either by force or stratagem, any advance of European travellers. It is not many years ago that observers were first able to measure the highest mountain in the chain, and probably in the whole world. This is the Gaurisankar, or Chingo-Pamari, the summit of which rises to a height of 29,002 feet, nearly twice the elevation of Mont Blanc. In the same range, up to the present time, two hundred and sixteen summits have been measured, seventeen of which exceed 24,600 feet in altitude, forty are about 23,000 feet, and a hundred and twenty more than 20,000 feet high. Next to the Gaurisankar, the highest known mountain is the Dapsang (28,297 feet) in the Karakorum.

The great peaks of the Himalaya, contemplated from one of the headlands which stand out far into the plains of Hindustan, form one of the most magnificent spectacles which the eye of man can see and wonder at. From the village of Darjiling, which the English have built upon a terrace more than 6,000 feet above the level of the sea, in order to enjoy a cold and bracing air like that of their native country, may be seen rising in all its formidable majesty the colossus of Kinchinjinga, nearly five miles high. At its base, as if in the bed of a gulf of verdure, a white torrent of foam glitters through the palm-trees; higher up, a chaos of wooded mountains, like the waves of a monstrous sea, are crowded and piled one over the other round the great tranquil summit; above the multitude of secondary peaks rise the long slopes of the mountain, first tinged with an aërial blue softer than that of the sky, then with a bright white, sparkling like silver. From one snowy ridge to another, the eye rises at last to the culminating point, from which the bold climber, if he ever reaches it, might see stretched out at his feet a prospect as extensive as that of the whole of France.

Spectacles as grand as that of the Kinchinjinga, seen from Darjiling, are numerous enough in the Himalaya, especially in the eastern portion of the chain, where the summits attain their principal elevation, and where the defiles of the valleys are most deeply hollowed out. But although these mighty mountains of Upper Asia are more majestic than the European Alps, they do not generally present an equal variety of aspect, an equal grace of outline, or charm of landscape. In all its grandeur, the Himalaya is uniform; its peaks are loftier, its snows more extensive, its forests deeper; but there are fewer cascades and lakes; there are no pleasant lawns and scattered groves; and we fail to notice the picturesque *châlets* nestling down in the glens or hanging over the brink of the precipices.

The South American Andes, which, in 1824—that is, before the discoveries of Webb and Moorcroft—were looked upon as superior in elevation to the Himalaya, are, in fact, 6,600 feet lower in mean height. In sublimity they are exceeded by the Asiatic mountains, in variety of site by the European Alps; but they are distinguished, especially in the volcanic regions, by regularity of form. Added to this, they constitute a chain which, in a geographical point of view, is really unique, on account of the harmony which they exhibit with the continent which they crown with their snowy ridges. This long range of mountains, so remark-

able by its enormous length (about 4,350 miles), and by the great height which its peaks maintain over a space of about 50 degrees of longitude, is, however, less regular than it appears at first sight. The principal characteristic which distinguishes the Andes from every other mountain system is found in the numerous forks, or rather bipartitions, of the Cordillera. In that part alone of their extent which stretches from the frontiers of Chili to those of Venezuela, the Andes divide eight times, forming large oval enclosures, each containing a plateau between the two lines of peaks. At some points, indeed, the Andes separate in three scarcely divergent branches.

From the southern point of America, as far as the other side of Aconcagua (22,420 feet)—the giant of the Chilian Andes—the principal chain throws out to the east but very unimportant groups. There are only some low ridges running above the *pampas* parallel to the principal ridge. About the 30th degree of latitude these uplands augment in number and height, and then form a vast plateau, from which, in a north-easterly direction, branches off the great sierra of Aconquija. Other *sierras* rise on the enormous mass of the plateau between the mountains of Aconquija and the great fork of the Bolivian Cordillera, in the 22nd degree of latitude. The western range, composed of broad domes of a regular shape, approaches the shore of the Pacific, whilst the eastern chain, throwing out several important branches into the eastern plains, curves round the great plateau of Bolivia, with its long row of serrated and snowy peaks, among which towers the Illampu or Sorata (24,812 feet), the highest mountain in America. North of the Lake of Titicaca the two chains are united by a transverse rampart, but they continue to extend in a north-west direction parallel to the coast. Although the eastern Cordillera is pierced at a great many points by rivers which are tributaries of the Amazon, it can still easily be recognised by the general direction of the fragments which compose it.

At the *knot* of Cerro de Pasco the two Cordilleras again unite, but only to divide again immediately into three chains, one of which, tending to the north-east, merges in the Pampa del Sacramento, whilst the two others, enclosing between them the deep valley of the Marañon, unite at the extreme angle near the southern frontiers of Ecuador. More to the north we have several small plateaux covered with virgin forests; then, on the other side of Loja, the two Cordilleras again separate their two parallel ridges of snow-clad summits. Here, too, lies the magnificent terrace of Ecuador, divided into three distinct plains by the cross groups of Assuay and Chisincha. Two of these plains, those of Tapia and Quito, form the magnificent avenues of volcanoes rendered celebrated by La Condamine, Bouguer, Humboldt, and other learned travellers. On one side rise Chimborazo, Carahuirazo, Illinissa, Corazon, and Pichincha; on the other, Sangay, the most formidable volcano in the world, Tunguragua, Cotopaxi, Antisana, and Cayamba, which crosses the line of the equator.

North of the equator, the two chains unite in forming the group of the Pasto plateau, which stretches nearly up to the second degree of latitude. At this spot commence three distinct Cordilleras, which are not destined again to unite into another knot of mountains. The western Cordillera disappears close to the Gulf of Darien, between the valleys of the Atrato and Cauca. The central Cordillera, on which rise the mighty summits of Puracé, Huila, Tolima, and Herveo, divides the Cauca basin from that of the Magdalena; lastly, the eastern Cordillera, or the Suma-Paz (supreme peace), bending round to the west of the plateau of Bogota, forks out into two chains near Pamplona, one of which terminates in the vicinity

of Maracaïbio, under the name of the Sierra-Negra; whilst the other, variously ramified, bounds on the north the *llanos* of Venezuela, and, forming the proud Silla of Caraccas, runs along the sea-coast and pushes out as a promontory to the Bouche-du-Dragon, which separates it from the mountains of the island of Trinidad. This point forms the termination of the chain of the Andes. The immense and spirally inflected extent of the Cordillera has for its culminating summits three peaks—Chimborazo, Sorata, and Aconcagua—placed about 1,240 miles apart on the mighty ridge; but the summits which are higher than Mont Blanc may be reckoned by hundreds. This enormous mountain chain seems to form so intimate a part of the very construction of the continent, that numbers of the inhabitants of its plateaux and slopes look upon it as the backbone of the whole world; they cannot fancy any country which is not commanded by the Cordillera of the Andes.

CHAPTER XXVI.

GRADUAL COOLING OF THE AIR ON MOUNTAIN SIDES.—DIFFICULTY OF ASCENTS.—LIMITS OF MAN'S HABITATION.—MOUNTAIN SICKNESS.

BY uplifting their summits into the higher regions of the atmosphere, mountains penetrate through zones of ever-increasing cold, and, owing to this gradation of successive temperatures, nature assumes a marvellous variety of climates and floras. The sides of every lofty mountain present a kind of epitome of all the phenomena which are exhibited in the immense space comprehended between the plains at its foot and the icy regions of the pole.

The solar rays have actually more heating power on the soil of mountains than in the plains, as is shown by direct observation, and also by the marvellous colours of the sweet-smelling Alpine flowers; therefore the gradual cooling of the temperature on mountain slopes must be attributed to the rarefaction of the successive layers of air. The investigations and experiments of natural philosophers have proved that the air affords a much easier passage to luminous than to dark radiations. The result of this fact is that the heat poured down by the sun during the day-time readily traverses the whole depth of the atmosphere in its way to warm the surface of the planet, whilst the heat radiated from the ground during the night can only escape into space in very small quantities. The lower layers of the atmosphere thus act as complete screens in arresting the radiation from the surface of the earth, and preventing the cooling of the planet. By this very fact, however, slopes and summits of mountains are, in proportion to their elevation, the more easily deprived of the heat which warms the plains at their base, and they mount into tracts of air which are the more chilled in proportion as they are vertically distant from the denser atmospheric layers lying below. Thanks to this progressive diminution of temperature in the aërial waves which bathe them, mountains, already so beautiful in their outline and the majesty of their forms, add to the magnificence of their appearance by the contrast between their forests and their glaciers, their pasture-lands and their snows.

What, then, on the average, is the proportion according to which the temperature falls in ascending from the base to the summit of a mountain? It is a difficult matter to settle it exactly, for aërial currents of various temperatures lie one above the other in the heights of the atmosphere, and sometimes we may rise from a comparatively cold zone to one that is much warmer, as some of the aëronautic expeditions of Mr. Glaisher have strikingly proved. Nevertheless, when the sky is clear and the air is calm, the decrease of the temperature takes place with a regularity which is sufficiently certain to enable us to calculate the

law respecting it, at least approximately. Just above the surface of the ground an elevation of 143 feet corresponds, on the average, to a fall of one degree Fahrenheit; at the height of about 3,000 feet it takes an increase of height of 294 feet to effect a diminution of heat amounting to one degree Fahrenheit; and in proportion as we mount higher and higher the interval increases, so that at about 30,000 feet of elevation the temperature sinks only one degree Fahrenheit for every space of 1,055 feet. The real rate of the decrease of heat cannot be so easily ascertained on the slopes of mountains, on account of the influence of the ground and the ice. But we may state generally that on the Swiss mountains the temperature of summer decreases one degree Fahrenheit for every vertical space of 290 feet; in winter the same fall of temperature takes place for every 439 feet of increased height.

The extreme cold of very lofty mountains renders them completely uninhabitable for man. Since the ascent of Mont Blanc by Jacques Balmat nearly a century ago, this mountain has been repeatedly scaled, but no traveller has ever set his foot on the mighty summits of the Karakorum and the Himalaya. The principal summits of the Andes—Sorata and Aconcagua—are equally inviolate; and even among the more unpretending summits of the Alps there are still a considerable number on which, up to the present time, the snows and the glaciers have formed a sufficient barrier against any attempted ascents. The highest point that the mountain-climber has yet attained is a summit of the Himalayas which rises 24,000 feet above the level of the sea. Even at this considerable height Johnston, who accomplished this exploit, still found himself more than 5,000 feet below the culminating point of Gaurisankar. Since this date, the aëronauts Glaisher, Crocé-Spinelli, and Gaston Tissandier have reached elevations many thousand feet higher in the cold atmosphere of Great Britain.

In all mountainous regions the permanent habitations of man cease at a limit far below the most elevated points reached by the bold mountain-climber. St. Veran and Gurgl, the most highly placed villages of France and Germany, are situated at the respective altitudes of 6,591 and 6,197 feet; but in Switzerland the Hospice of St. Bernard, built many centuries ago to shelter travellers when benumbed with the cold, is much more elevated, its height being 8,110 feet. There is another convent, that of Hanle, inhabited by twenty Tibetan priests, which is the most elevated cluster of houses in the whole world; it is situated at a height of 14,976 feet. None of the villages of the Andes, except perhaps that of Santa-Anna, in Bolivia, have been built at so great a height.

Travellers who venture to ascend the slopes of a lofty mountain not only have to suffer all the rigours of cold and run the risk of being frozen on their route, but they may also experience most painful sensations owing to the rarefaction of the air. It is, in fact, very natural that, at an elevation at which the pressure of the atmosphere is reduced to one-half, or even to one-fourth, that of the plains below, a certain uneasiness should be caused by the sudden change; and the more so, that some of the other surrounding conditions, such as the caloric and the humidity of the air, also become modified. Undaunted climbers like Tyndall, who have never felt in their own persons the effect of this mountain sickness, expressly deny that this exhaustion proceeds from anything else than mere fatigue. M. Jules Remy, too, has noticed only one mountain of the Andes on which the phenomena of the *puna* or *soroche* are *always* developed in the organism of livings beings; this is the Cerro de Pasco, the height of which does not exceed 13,966 feet. Horses, mules, asses, and oxen are also, like man, subject to the

peculiar influence of these localities; whilst at much more considerable altitudes the usual state of health suddenly returns. Therefore, in this region of the Andes, emanations from the ground, and not the rarefaction of the air, are the cause to which some have attributed the inconvenience felt by travellers. But the observations of many travellers and the investigations made on the subject by Robert von Schlagintweit can leave no doubt in our minds that this mountain ailment is really felt generally, in other regions of the Andes as well as on the Cerro de Pasco. Usually, indeed, the effects of the *soroche* are felt at a much lower elevation on the slopes of the Cordilleras than on those of the Himalaya. In the latter mountains the traveller does not begin to suffer from the attacks of this ailment until he has reached a height of 16,500 feet, whilst on the Andes a large number of persons are affected by it at an altitude of 10,700 and 11,500 feet. Added to this, in the South American mountains the symptoms are much more serious; to the fatigue, headache, and want of breath, which are likewise experienced on the Himalaya, are added giddiness, sometimes fainting-fits, and bleeding from lips, gums, and eyelids. At the same elevation as the *paramos* of the Andes, or even as the lofty summits of the Himalaya, the aëronaut—who, however, is spared all the fatigue of climbing—rarely suffers any inconvenience; but at 30,000 to 40,000 feet the malady shows itself, and if the balloon continued to rise, the aërial voyager would infallibly perish. Therefore, at but a very few miles above our heads lies the region of death, and into this terrible zone the loftiest mountains of the earth elevate their white summits.

From Gavarret's observations it is evident that during the ascent of mountains the blood loses oxygen by the diminished pressure, and becomes gradually poisoned by the excess of carbonic acid. Nevertheless the inhabitants of upland plateaux at last become completely acclimatised, while their domestic animals adapt themselves still more rapidly to the changed surroundings. At these elevations the blood becomes enriched with hemoglobine, and thus gradually recovers its normal quantity of oxygen. Analysis shows that the blood of animals on the La Paz plateau (12,300 feet) contains nearly twice as much hemoglobine as that of graminivorous mammals in the west of Europe. It has also been observed that at a certain altitude spirits lose their intoxicating effect. Such at least is the statement of H. de Saussure, since confirmed by Orton and other travellers. At Quito drunkenness is an unknown evil.

CHAPTER XXVII.

GRADUAL SUBSIDENCE OF MOUNTAINS DURING THE LAPSE OF AGES.—SUDDEN LANDSLIPS.—THE FALL AT FELSBERG AND ELM.—SLOW ACTION OF METEORIC AGENCIES.

THE formidable mountain citadels which tower up so high over the habitations of man, along the sides of which creep clouds and thunder, do not, however, escape a slow but certain process of sinking so soon as the upheaving force which pushed them out of the earth has ceased to act. Assisted by the force of gravity which is constantly tending to level the surface of the ground, meteoric agents are unceasingly persistent in the destruction of mountains. They open valleys and gorges, they hollow out passes, they undermine their summits, either by sudden landslips, or, more generally, by a slow and continuous erosion. Sooner or later, the Andes and the Himalaya, those mighty continental ridges, will become mere ranges of hills, like many another ancient mountain-chain, which, also, once formed the backbone of a world.

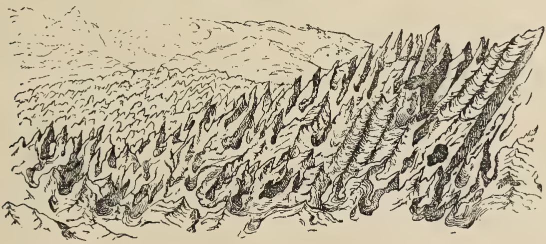
Rain, snow, frost, and especially thaws, as well as the winds and solar heat, although in a less degree, are incessantly at work demolishing mountains. "Firm as a rock" is a proverb current only amongst lowland populations. Highlanders are more alive to the solidity of a wall than to that of a cliff; for they have often learnt by dearly bought experience how fragile is the rock exposed to atmospheric influences. In the Alps, mountains known by the name of "Ruin" or "Crumbling" are very numerous, and most of them deserve these names, from the visible weathering of their rocky slopes. According as they are composed of granite, porphyry, lavas, schists, sandstones, or limestones, they become diversely corroded, and in some places so rugged as to be quite impassable by pedestrians. Remarkable instances are the Karren of Santis, the Brigelserhorn, and several of the peaks of the Grand-Paradis.

Great landslips, although of no very great importance in a geological point of view, are among the most tremendous phenomena of planetary vitality; whenever such a catastrophe has occurred, tradition has handed down the recollections of it for long centuries. No event is calculated to produce a more forcible effect on the popular mind. Perpendicular or overhanging rocks, which seem to hang suspended over the plains, suddenly become detached and rush headlong down the mountain side; in their rapid fall they raise a cloud of dust like the ashes vomited forth by a volcano; a horrible darkness is spread over the once pleasant valley, and the cataclysm is known only by the trembling of the ground and the crushing din of the rocks striking together and shattering one another in pieces.

When the cloud of dust is cleared away, nothing but heaps of stones and rubbish are to be seen where pastures and cultivated land once were; the stream flowing down the valley is obstructed in its course and changed into a muddy lake; the rampart of rocks has lost its old form, and on its sides, from which some *débris* are still crumbling down, the sharpened edges point out the denuded cliff from which a whole quarter of the mountain has broken away. In the Pyrenees, Alps, and other important chains, there are but few valleys where we may not notice these chaos-like heaps of fallen rocks.

The principal catastrophes of this kind which have taken place in the moun-

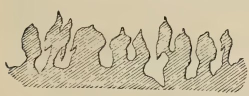
Fig. 48.—Karrens of Santis.



tains of Europe during the present era are facts which are well known. Southward of Plaisance, in Italy, the ancient Roman town of Velleja was buried about the fourth century by the downfall of the only too well named mountain of Rovinazzo, and the large quantity of bones and coins that have been found proves that the subsidence of the rocks was so sudden that it did not even afford the inhabitants any chance of escape. Tauretunum, another Roman town, situated, it is said, on the banks of the Lake of Geneva at the base of one of the spurs of the Dent d'Oche, was completely crushed in A.D. 563 by a downfall of rocks; the declivity

Fig. 49.—The Brigelserhorn.

Fig. 50.—Section of the Karrens.



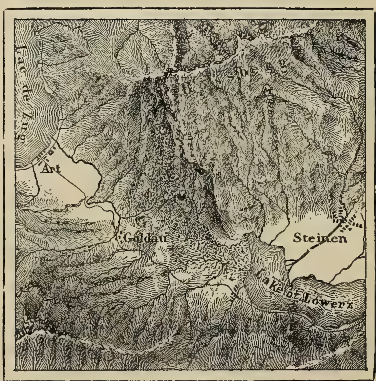
that it formed may still be seen advancing like a headland into the waters of the lake, which at this spot is not less than 520 feet deep. A terrible flood-wave, produced by the deluge of stones, invaded the opposite shores of the lake and swept away all the habitations; from Morges to Vevey every town and every village on the banks was demolished, and they did not commence to rebuild them until the following century. Geneva itself was in part covered by the water, and the bridge over the Rhone was swept away. According to MM. Troyon and Morlot, however, these disasters were caused by a landslip which fell from the

Grammont or Derochiaz across the valley of the Rhone, just above the spot where it flows into the lake of Geneva. The effect of this was the formation of a temporary lake, and the shores were devastated by an inundation at the time of the destruction of the natural barriers by the accumulated water.

Fig. 51.—Summit of the Grand-Paradis.

The great avalanches of rocks which have taken place during historical periods in the Alps and neighbouring mountains may, in fact, be reckoned by hundreds. In 1248, four villages situated at the base of Mont Granier, not far from Chambéry, were buried under a mass of calcareous rubbish, which the watercourses have now ravined out and moulded into little hillocks; small pools, known by the name of *abimes,* are dotted about amongst these heaps of *débris,* which are nowadays covered with cultivation. In 1618 the downfall of Monte Conto buried the 2,400 inhabitants of the village of Plurs, near Chiavenna. Two out of the five peaks of the Diablerets fell down, one in 1714, and the other in 1749, covering the pastures with a layer of *débris* more than 300 feet thick, and obstructing the course of the stream of Lizerne, formed the three lakes of Derborence, which are now existing. In like manner, the Bernina, the Dent du Midi, the Dent de Mayen, and the Righi have overspread with their fragments vast tracts of cultivated land. But no catastrophe of this kind has left more fearful reminiscences of horror than the fall of a section of the Rossberg, on the 2nd of September, 1806. This mountain, situated to the north of the Righi, in the centre of the peninsula-like space formed by the lakes of Zug, Egeri, and Lowerz, consists of a compact conglomerate, lying on beds of clay, which hinder the infiltration of the surface water. At some unknown epoch the falling rubbish of a mountain spur destroyed the village of Rotten; but in 1806 the catastrophe was still more terrible. The season which had just terminated had been very rainy, and the clay strata had gradually changed into a muddy mass; at last, the rocks above, losing their supporting basis, began to slip down the mountain side, ploughing up the ground in front of them as the bow of a ship cleaves the water before it. Suddenly a general break up took place. In a moment, an enormous mass, carrying with it its forests, meadows, hamlets, and inhabitants, rushed down into the plain. Flames, produced by the friction of the rocks striking and rubbing against one another, broke in fiery jets from the half-opened moun-

Fig. 52.—Great Landslip of Goldau.



tain. The water deposited in the deep beds, suddenly converted into steam, burst out with explosive force, and showers of mud and stones were vomited as from the mouth of a volcano. The charming plains of Goldau (the Vallée d'Or), and four villages, inhabited by nearly a thousand persons, disappeared under the heaps of *débris ;* the Lake of Lowerz was partly filled up, and the furious wave which the falling mass drove up on to the banks swept away all the houses on it. The cata-

Fig. 53.—Landslip of Elm.

Buildings destroyed by the landslip.
Buildings preserved.
Débris of the landslip.
Watercourses filled up.

strophe occurred in so sudden a way that the very birds were killed as they were flying in the air. The portion of the mountain which slipped down was not less than two miles and a half long, by about 350 yards wide and 35 yards thick ; it was a mass containing more than fifty-four millions of cubic yards.

A less serious but more carefully studied landslip occurred in 1881 in the Swiss valley of Seruf, by which half the village of Elm was overwhelmed. The disaster

was due to want of due precaution on the part of the quarrymen, who went on, probably for ages, undermining the steep slate cliffs without taking care to support the ground. First a crevasse appeared as a warning above the quarries, and this became every year wider and deeper, until at last a solid mass, estimated at 350 million cubic feet, suddenly gave way above the village of Elm. A column of air preceding the avalanche sent châlets, trees, and men whirling over the valley, whilst on either side of the current the atmosphere remained perfectly still. Further down the masses of earth and slate spread like a lava stream over the surface at a velocity of 400 feet per second.

THE CIRCULATION OF WATER.

CHAPTER XXVIII.

SNOW-FALL ON MOUNTAINS.—LOWER LIMIT OF SNOW.—ZONE OF PERPETUAL OR PERMANENT SNOW.

THERE are few sights more charming than that of the clouds sweeping in long trains over the sides of a mountain, and leaving behind them on the slopes a covering of fresh-fallen snow. We may often notice that the lower portion of a cloud breaks up into showers, and inundates with rain the less elevated slopes, whilst higher up the colder vapours are discharged in flakes of snow. A line, which is sometimes uncertain, but is usually pretty definitely traced across the declivity of the mountain, marks out the limit of temperature above which the clouds fall in snow, and runs with remarkable regularity above the verdant tracts which have been watered by the rain.

This lower snow-limit is traced round the mountain side at different elevations, according to the seasons. In winter it gradually descends to the base of the Alps and Pyrenees; in spring and summer it rises little by little towards the summits, and even mounts above them when they do not reach any very great elevation. For the most part, however, the higher mountain-chains have their ridges always covered with snow, and a line may be drawn across their declivities, changing more or less in various centuries and years, above which the snow never entirely melts. This is the so-called *snow-line* or limit of the perpetual snow; it would be better described as the limit of *permanent* snow.

Above the lower snow-line the snow is constantly being partially melted and then again renewed; thus the bed of snow-flakes becomes gradually thicker and more heaped up, owing to the fall of the temperature in these high regions. More snow, in fact, falls than the rays of the sun and the heat of the earth can dissolve in one warm season; enormous masses, therefore, fill up all the gorges and ravines, and drifts of several yards in depth cover those rocks and cliffs which are not too steep to allow the snow to accumulate on their slopes. All lofty mountains are, therefore, clad with mantles of snow; but it is certain that if they rose to a still more considerable elevation into the regions of air, they would ultimately, and indeed

before long, reach a limit-line above the very snow itself. In fact, the cold regions of the higher atmosphere contain only a very small proportion of misty vapour; and the scanty flakes of snow which would fall on summits 45,000 to 60,000 feet high (if any such existed) would be soon swept away by the wind or melted by the solar rays. On the sides of a mountain of this elevation there would be a belt of permanent snow, bounded on the lower side by a region of pasture-ground, and on the upper by tracts of desert perfectly devoid of vegetation. According to Tschudi, the quantity of snow which falls on that portion of the Alps which is above a height of about 10,800 feet is comparatively very small. Most of the clouds charged with snow-flakes discharge their burden on the mountain slopes at elevations of 7,600 to 8,600 feet. At these heights moisture falls sometimes also in the form of rain; but at 10,000 feet the clouds but rarely assume the shape of showers, and at 12,000 feet they bring nothing but snow. Observations made in the Alps prove, however, that the quantity of snow falling on different mountains varies singularly, according to the altitude and the aspect of the slopes, and in each particular locality, according to the climatic circumstances of the year. At the Hospice of Grimsel, situated at a height of 6,148 feet, M. Agassiz noticed a fall of snow in six months of winter amounting to 57½ feet, equivalent to 5 feet of water. Some years afterwards, in the same place, W. Huber ascertained that the thickness of the bed of snow was 59 feet during a period of double this duration. On the St. Bernard, at 8,110 feet of altitude, the thickness of snow has varied during twelve years (from 1847 to 1858) from 11½ feet to 44¼ every year. This would give a difference of 1 and 4 in a yearly snowfall on the same point of the mountain. It appears that on the St. Gothard, at an elevation of 6,867 feet above the level of the sea, the annual deposit of snow is more considerable than on the St. Bernard; for in one night's time the thickness of the fallen snow was sometimes increased as much as 6½ feet. The snow which falls on the mountain summits is but seldom composed of those elegant shapes, the marvellous configuration of which we so much admire in the valleys. It usually consists of small granules as fine as dust, slender needles of ice, and stars with almost imperceptible rays; it is, in fact, sleet, and not snow, properly so called. It often happens that the slightest change in the direction of the atmospheric currents substitutes a fall of granular snow for one composed of flakes, or produces the reverse phenomenon. We cannot, however, as Agassiz has pointed out, establish any well-defined distinction between the two different kinds of sleety or flaky snow. As a rule sleety and granulated snow occurs only between the temperatures of -11 and $+4$ Centigrade, while in severe cold it rarely snows.

It is very difficult, or, indeed, impossible, to fix the altitude above which beds of snow may always be perceived on various groups of mountains. This limit varies according to the aspect and inclination of the slopes, the nature and colour of the rocks, the force and average direction of the winds, the quantity of the snow which falls, and all the meteorological phenomena of the region into which the summits rise. It is, therefore, only approximately, and entirely in a general way, that we can venture to point out the height of this unsettled line, fluctuating, as it does, from year to year, and from century to century, under the combined influence of solar heat and atmospheric agencies. According to the brothers Schlagintweit, the so-called limit of perpetual snow in the central Alps would fluctuate between 9,000 and 9,240 feet of altitude, and for the group of Mont Blanc between 9,400 and 10,200 feet. Nevertheless, it is very certain that in September, 1842, a neighbouring mountain to the Jungfrau—the Ewigschneehorn, the German name

of which signifies *peak of eternal snows*—showed nothing but the bare ground on all its slopes. In like manner, in 1860 and in 1862 the summits of the Alps presented only partial stains of white snow, and tourists could cross the Strahlech (10,993 feet) without walking for a single instant on any snow, either fresh or hardened. In 1855 Sonklar could not perceive a trace of snow on the Hangerer, a mountain in the Austrain Alps, which rises to a height of 9,994 feet. Similarly, in the autumn of 1859, the summit of the Chaberton (10,295 feet), near Mont Genèvre, was completely bare of snow. With regard to the Pyrenees, in which the limit of permanent snow would be from 9,000 to 9,240 feet in height, it is certain that the Montcalm, which rises to an elevation of 10,101 feet, is topped by a kind of plateau which is often perfectly clear of snow during the hot season, and even dotted over with bunches of grass. On the Spanish side of the Pyrenees, towards the middle of August, nothing but the bare rock is to be seen, except in the deep hollows which the south wind cannot penetrate. The ideal snowy zone with which geographers clothe the lofty Pyrenean peaks has, in fact, no absolutely permanent existence.

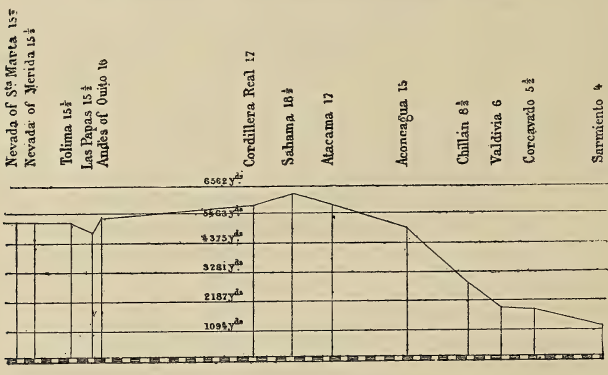
The same thing may be likewise affirmed of a large number of mountain chains that we are accustomed to class with those which are crowned by perpetual snow. The ideal line, therefore, which is traced in most atlases as fixing the limits of the snowy zone on the outline of mountains can only be considered as having an approximate value. The lower slopes even of the Spitzbergen, Franz-Joseph Land, and Jan Mayen mountains are free of snow in summer; and during the same season the snow-line falls to 2,800 or 3,000 feet in Greenland.

According to Durocher, the line of perpetual snow, which passes at a height of 13,731 feet over the sides of the equatorial Andes, would be only 705 feet lower than on the great mountains of Mexico—Popocatepetl and Orizaba. There is another phenomenon which is much more surprising still: in the southern hemisphere, south of the Peruvian Andes, this snow-line ceases to sink, and even rises to more than 16,500 feet of altitude. On the plateaux of the Chilian and Argentine Andes, between 22 and 33 degrees of south latitude, where the temperature naturally falls much lower than in the corresponding regions of Ecuador, the mean limit of snow is actually higher, which, no doubt, is owing to the great dryness of the winds. Thus travellers have seen the slopes of the Cordillera of Mendoza, on the 22nd degree of latitude, swept perfectly clear of snow up to the height of 13,200 feet; at four degrees farther north no white surface is seen to glitter on the Sierra Famatina (14,764 feet). In the Tropic of Capricorn, the Sierra de Zenta, the summits of which rise 16,404 feet above the level of the sea, is but very rarely covered with snow even during the winter, and the layers of flakes which are brought by the clouds immediately melt. Lastly, according to Pentland, the western slopes of the Bolivian Andes, which are very seldom exposed to damp winds, exhibit no instances of perpetual snow at a less height than 18,370 feet. In a general way, any humidity that falls evaporates without giving rise to the smallest rivulet of water, or even without moistening the ground. Towards the middle of the day, the clouds may be seen from afar floating up from the heights of the mountains like smoke, and disappearing at an immense altitude in the deep azure; these are the snows of yesterday reascending into the atmosphere in the form of vapour.

The astonishing contrast, as regards the lower snow-limit, between the northern slopes and the southern side of the mountain-chains of Central Asia, must be attributed to the unequal distribution of the rainfall. The climate is naturally

much more rigorous on the north side of the Himalaya than in the valleys turned towards the south, and yet in the former the snow-covered tracts do not descend nearly so low. This contrast is so striking that every traveller has remarked it, and has even exaggerated its importance, until the recent explorations of the brothers Schlagintweit. According to Hooker, the botanist, on the southern sides of the Himalaya the mean limit of perpetual snow exceeds 13,943 feet, and on the opposite slope rises to 18,589 feet of altitude; so that precisely the coldest side is denuded of snow at a point 4,646 feet higher than the declivities exposed to the burning sun of Hindustan. The comparative observations of the brothers Schlagintweit have considerably reduced this enormous difference between the two slopes. For the southern and northern slopes, these travellers have ascertained the mean limits to be respectively 16,049 feet and 17,237 feet, which reduces the total difference to 1,188 feet. But farther on in these regions the contrast may be made more considerable, for in Tibet many mountains at an altitude of even more than 20,000 feet may be seen denuded of every snowy particle. This great height of

Fig. 54.—Limit of Permanent Snow in South America.



the snow-limit on the northern slopes of the Himalaya was attributed by Humboldt to the reaction of the solar rays after falling on the plateaux of Central Asia; but the brothers Schlagintweit, by showing that Tibet is actually a large valley of mountains, and not a plateau, have put it beyond doubt that the cause of this contrast between the snowy slopes must be sought for in the system of winds. On the north, the aërial masses which sweep over the Himalaya after having traversed the whole of Central Asia are perfectly dried up; but on the south, the monsoons which rush stormily through the gorges of Nepal and Sikkim are charged with an enormous burden of moisture, which falls in snow on the high summits and in rain on the valleys beneath.

On the mountain-chains which extend to the north of the Himalaya the mean limit of perpetual snow descends regularly as the chains lie farther north. In the Karakorum, where this ideal line is higher than in the Himalaya, on account of the great dryness of the air, the respective altitudes are, in the southern chain, 19,225 feet, and in the northern slope 18,438 feet; in the Kuen-Lun, they are, on the south, 15,640 feet, and 14,960 feet on the north. As regards the other chains of

Central Asia, no exact observations have been made, except for the Altaï, in which the mean limit of perpetual snow is at 7,034 feet.

In a general way it is assumed that at about the 75th degree of north latitude the snow-limit coincides with the level of the sea; but, as Richardson has shown, no arctic regions have yet been discovered which in the height of the summer are covered with a permanent layer of snow, and very probably none such exist. Therefore, as regards these polar countries, as well as for most of the mountains in the temperate zones, the expression "perpetual snow" ought to be erased from scientific phraseology. We must also refrain, notwithstanding the example set us by many meteorologists, from laying down any general law in reference to the mean limit of snow; for the atmospheric phenomena in the various parts of the world are not yet sufficiently well known, and the distribution of heat, the direction and humidity of the winds, vary quite as much as the forms of the continents themselves.

The more important point, therefore, is not the mere recognition of the uncertain and variable line of the lower snow-limit on mountain slopes, but the establishment, as regards the most varied points, of the mean quantity of snow which falls annually on the sides and summits of mountains, these facts being derived from observations carried on season after season and year after year. In like manner, as regards a river, neither the low-water mark nor the point reached by the highest floods is the fact which is the most essential to ascertain, for these levels relate but to an instant of fluviatile vitality, and their sole value is only as a means of comparison with other such levels; the more useful questions are the mean discharge of the flow of water and the resultant presented by the incessant fluctuations of the stream.

CHAPTER XXIX.

INFLUENCE OF THE SUN AND METEORIC AGENTS ON THE SNOW.—AVALANCHES.—PROTECTING FORESTS.—DEFENSIVE WORKS AGAINST AVALANCHES.

THE accumulated layers of snow do not remain for ever on the sides and summits of mountains. Since every year, on the average, 33 feet of snow fall on the mountains of the Alps, these peaks would, in fact, in the course of a century, increase 3,300 feet in height, if the humidity falling from the clouds in the form of snow-flakes was not evaporated into the atmosphere, or did not find its way down into the valleys below.

The heat of the sun and meteoric influences commence the work of clearing away the snow. It has been calculated that the solar rays will melt as much as 20 to 28 inches of snow in a day, especially when the upper layers are not very dense, and allow the heat to penetrate to some depth under the surface. The rain and tepid mists which the winds convey on to the mountain slopes also lend their aid in thawing the snowy layers, and sometimes indeed with more effect than the rays of the sun. The cold winds likewise assist by blowing up the snow into whirlwinds, and thus transferring it to lower slopes where the temperature is higher. There is not one violent wintry squall which does not remove thousands of cubic yards of snow from the summits of lofty mountains, as may easily be seen from below, when the peaks beaten by the wind appear to smoke like craters, and the powdered flakes are dispersed in whirlwinds. The warm and dry winds, however, effect still more than storms in diminishing the masses of snow which lie heavy on the summits. Thus the south wind, which is called *föhn* by the Swiss mountaineers, will in twelve hours melt or cause to evaporate a bed of snow three-quarters of a yard thick. It "eats up the snow," as the proverb says, and brings spring back again on the mountains. Next to the sun, the *föhn* is the principal climatic agent in the Alpine districts. In his admirable treatise on Mont Blanc, Viollet-le-Duc describes the various forms assumed by snow under the influence of the wind and the form of the slopes and projections on which it is lodged. In July, 1872, some remarkable effects of this sort were seen at the Morning Pass.

It would be very important if we could establish the average proportions of the masses of snow which fall upon the mountains which are lost by melting and evaporation respectively. In valleys where the sides are composed of hard rocks which retain the water on the surface, it would suffice to measure the annual discharge of the torrent, and to compare it with the quantity of rain-water and snow which has fallen in the basin during the same period, and we should approximately ascertain all that has been lost *en route*, being drawn from it either

by the innumerable roots of the plants growing in it, or directly by evaporation. At all events, it is certain that this latter cause of diminution is very important, for even during calm weather, and at three or four degrees below freezing-point, the superficial surface of the snow constantly supplies to the atmosphere a certain portion of aqueous vapour. Under the influence of the sun and wind evaporation increases very rapidly.

But these slow and gradual means are not the only causes of the diminution of the mountain snows; they also sink down in masses into the valleys, and thus expose themselves directly to the influence of heat. The masses which thus rush down the slopes are avalanches, likewise called in the Alps *lavanges* and *challanches.* The greater part of these downfalls of snow occur with great regularity, so much so that an old mountaineer, who is clever at discerning the signs of the weather, can often announce by a mere glance at the surface of the snow the exact time at which the subsidence will take place. The path of the avalanche is completely marked out on the mountain side. At the outlets of the wide mountain amphi-

Fig. 55.—Cornice of Snow at the Morning Pass, July, 1872.

theatres in which the snows of winter are accumulated, narrow passages open, hollowed out in the thickness of the rock. Like torrents, only that they appear but for a moment and are suddenly gone, the masses of snow which are detached from the upper declivities rush down the inclined beds afforded them by the narrow passages, and descend in long trains, until, arrived at the ledge of their ravine, they pour out over the slope of *débris.* Most mountains are furrowed over their whole extent with vertical channels, down which the avalanches rush in the spring. These falling masses become actual tributaries of the streams which run below; only, instead of flowing continuously as the rivulets of the cascades, they plunge down all at once, or in a succession of falls.

On slopes where the inclination exceeds 50 degrees the snows not only descend through the passages hollowed out here and there on the mountain sides, but they also slide *en masse* over the escarpments. Their gradual progress being more or less rapid, at first they accumulate in heaps when they meet with any obstacle in the less sloping portions of their track, until, becoming animated with a sufficient momentum, they at last break forth with a crash, and dash down into the depths

below. The particular way in which each avalanche descends is, of course, varied according to the shape of the mountain. On perpendicular escarpments the snow on the upper terraces is slowly impelled by the pressure of the masses above it, and plunges over straight down into the abyss below. In spring and summer, when the white layers, softened by the heat, are falling away every hour from the lofty summits of the Alps, the mountain climber, standing on some adjacent headland, may contemplate with admiration these sudden cataracts dashing down into the gorges from the heights of the shining peaks. How many thousands of travellers, seated at their ease on the grassy banks of the Wengernalp, have witnessed with exclamations of pleasure the avalanches rolling down to the base of the silvery pyramid of the Jungfrau! First the enormous bed of snow is seen to plunge forth like a cataract, and lose itself in the lower stages of the mountain; whirlwinds of powdered snow, like a cloud of bright smoke, rise far and wide into the atmosphere; and then, when the snow-cloud has passed away and the whole region has again assumed its solemn calm, the thunder of the avalanche is suddenly heard reverberating in deep echoes in the mountain gorges; one might fancy it was the voice of the mountain itself.

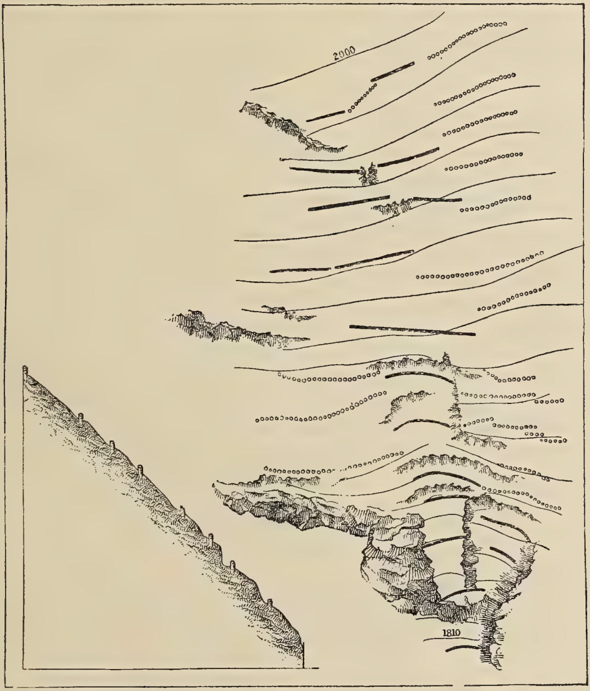
The avalanches known under the name of *poudreuses* are those most dreaded by the inhabitants of the Alps, on account not only of the ravages immediately arising from them, but also of the whirlwinds which frequently accompany them. Before the newly-fallen layers of flakes sufficiently adhere to the former snow, the mere tread of the chamois, the fall of a branch from some bush, or even a resounding echo, is sufficient to disturb the unstable balance of the upper sheet of snow. At first it slides slowly over the hardened mass beneath, until, reaching a point where the slope of the ground assists its progress, it rushes down with an increasingly rapid movement. Every moment it becomes augmented by fresh beds of snow, and by the *débris*, stones, and brushwood, which it hurries along with it. It makes its way over the ledges and passages, tears down the trees, sweeps away the *châlets* which lie in its path, and, like the downfall of the side of a mountain, plunges into the valley, sometimes even reaching the opposite slope. All round the avalanche powdery snow rises in broad eddies; the air, being compressed laterally by the sinking mass, roars right and left in actual whirlwinds, which shake the rocks and uproot the trees. Thousands of trunks may sometimes be seen thrown down by nothing but the wind of the avalanche, when the latter traces out for itself a wide path across whole forests, and, as it passes, sweeps away the hamlets in the valley.

The *avalanches de fond* are generally less dangerous than those we have just spoken of, because they are formed at a more advanced season of the year, when the greater part of the superficial snow is melted, and the remainder of the mass is able to run through its regular passages. As their name indicates, these avalanches are composed of the whole thickness of the snow-field. Lubricated, as it were, by the rivulets of water which cross them and flow over them, the beds of snow lose their adherence to the ground, and slide in one lump, like marine icebergs detaching themselves from a field of ice. Under the pressure of these moving masses, the snow below at last yields, and the avalanche, loaded with water and mud, earth and stones, rushes through the passages and over the rocks; at last, finding its way into the valley, it dams up the stream with a kind of dyke, which sometimes resists the weight of the water till the middle of summer, and the gray or even blackish mass becomes so compact that it assumes the hardness of rock. It is, in fact, a glacier in miniature.

Thickly-planted trunks of trees are the best protection against avalanches of every kind. In the first place, the snow which has fallen in the wood itself cannot very well shift its place; and then, when the masses descending from the slopes above dash against the trees, they are unable to break through so strong a barrier. After having overturned some few of the first trees, their progress is arrested, and the intermingled heaps constitute a fresh obstacle for future avalanches. Small shrubs, such as rhododendrons, or even heaths and meadow grass, are very often sufficient to prevent the slipping of the snow, and where

Fig. 56.—Defensive Works against Avalanches above De Louèche.

Scale 1 : 2,000.



—— Ramparts. ooooooo Plant .tions.

people are imprudent enough to cut them on the mountain slopes, they run the risk of clearing the way for this formidable scourge. The danger is still more imminent if a screen of trees is cut down in one of the protecting forests. The task is then begun for the avalanche, which soon undertakes to complete the rest of the labour by tearing up all that still remains of the former woody rampart. A mountain which stands to the south of the Pyrenean village of Aragnouet, in the lofty valley of the Neste, having been partially cleared of trees, a tremendous avalanche fell down, in 1846, from the top of a plateau, and in its fall swept away more than 15,000 fir-trees.

The protecting woods of Switzerland and the Tyrol used to be defended by the national *bann*, and, as it were, "tabooed." They were, and still are, called the *Bannwœlder*. In the valley of Andermatt, at the northern foot of the St. Gothard, the penalty of death was once adjudged on any man found guilty of having made an attempt on the life of one of the trees which shielded the habitations. Added to this, a sort of mystic curse was thought to hang over this impious action, and it was told with horror how drops of blood flowed when the smallest branch was broken off. It was true enough that the destruction of each tree might perhaps be expiated by the death of a man.

The inhabitants of some villages which are threatened with avalanches endeavour to find a substitute for trees in long stakes or piles driven into the ground to resemble fir-trees. This is what they call *clouer l'avalanche* (nailing up the avalanche). At the same time, they hew steps at intervals, almost like a staircase, so that the snow falling from the cliffs may be arrested in its course or partially broken up. In some localities, too, they construct lateral walls on purpose to contain the flow of the avalanche as if it were a banked-up river; and if, after all these precautions the houses are still threatened, they furnish them, like the piles of a bridge, with spurs or buttresses, made of stone or hardened snow, which, by sprinkling, is gradually changed into ice.

The village and the great establishment of the baths at Barèges, in the Pyrenees, used to be menaced every year by avalanches rushing down from an elevation of 4,000 feet, at an angle of 35 degrees. The inhabitants, therefore, were in the habit of leaving vacant spaces between the two quarters of Barèges, so as to allow a free passage to the descending masses. Lately, however, they have endeavoured to do away with the avalanches by means somewhat similar to those employed by the Swiss mountaineers. They have thrown up banks about 10 or 12 feet broad on the sides of the ravines, and have furnished these banks with an edging of cast-iron piles. Basket-work, and, here and there, walls of masonry, protect the young growing trees, which are gradually improving under the protection of these defensive works. In the meantime, until the real trees are strong enough to arrest the course of the snow, the artificial trees have well fulfilled the end they were destined for. In 1860, the year when the defensive works were finished, the only avalanche which slid into the ravine did not exceed 400 cubic yards in bulk; whilst the masses which used to fall down upon Barèges sometimes attained to more than 90,000 yards in volume.

In Switzerland some still more important works have been carried out for the purpose of protecting the Louèche baths from avalanches of snow.

CHAPTER XXX.

GRADUAL TRANSFORMATION OF SNOW INTO ICE.—NÉVÉS, OR GLACIER RESERVOIRS.—PHENOMENON OF REGELATION.—CRYSTALS OF ICE.—GLACIERS OF THE FIRST AND SECOND ORDER.

BY a succession of partial changes affecting the millions of frozen particles, the snow of the high mountain summits is changed into ice, and the white flakes falling on the peaks become those rivers of bluish crystal which slowly make their way down between the sides of the gorges. Imperceptibly the field of snow is changed into *névé*, and then into glacier; afterwards becoming in succession stream, river, and wave, it finally, under the form of aqueous vapour, recommences its eternal circuit.

The alteration of opaque snow into transparent ice is one of the most interesting phenomena of glaciation. The newly-fallen flakes begin by first settling down and hardening. Then, when the rays of the sun have raised the temperature of the snow-field to melting-point, a number of small drops penetrate into the subjacent layers, and, being again assailed by the cold, freeze into small envelopes, irregularly crystallized round solid molecules, and become cemented all together into a compact mass. The snow may thus become very hard, and on the edge of many of the precipices it forms a kind of overhanging pent-house, which resists for a considerable time the effects of the weather without giving way. We borrow from Forbes the design of one of these elegant cornices, with its brilliant pendants of ice.

In the end, the entire thickness of the snow-field changes its structure and becomes a mass of granules, from which the air is partially expelled by the successive freezing and melting produced by the solar heat. In this way are formed the hard and granular beds of former snow, which lie upon the upper slopes of all lofty mountains. These whitish or dull gray masses are known in the Alps and Pyrenees by the name of *névés*. In winter, when the temperature often remains below the freezing-point, even during the daytime, the snow on high summits maintains its powdery state; but as soon as it is subjected to the first breath of spring it begins to assume a granular form.

This first change in the particles of snow is but the prelude to still more important modifications. The heat of the sun continues to melt the surface-layers, and thus causes drops of water and laminæ of ice of an increasing size to penetrate into the *névé*. Simultaneously the snow, compressed by its own weight, ultimately expels by mechanical force the greater part of the air which it contains, and gives to the opaque granules of the *névé* the structure and transparency of ice. The pressure of the superincumbent layers is the principal agent in the transformation

of beds of snow. The brothers Schlagintweit and Tyndall state that by the compression of fresh snow they succeeded in obtaining slabs of transparent ice; but there is scarcely a child who has not amused himself in trying the same experiment by kneading a snowball with his fingers. Under the tread of the pedestrian, the coating of snow which sticks to his shoes ultimately becomes a piece of ice.

In consequence of this gradual transformation, the mass of *névé* becomes more and more indurated and compact. A cubic yard of snow weighs on the average 187 lbs.; but the same volume of *névé* weighs more than half a ton, and the various modifications to which the snow is subject in becoming transparent ice ultimately give it a weight of about 1,980 lbs. per cubic yard. The material which constitutes the glaciers is twelve times lighter than water when it commences its course, but at the end of its career it is only one-tenth or one-twentieth part inferior in weight to an equal liquid volume.

Notwithstanding these successive changes, the whole thickness of the mass of *névé* is composed of strata of varying regularity, which are the beds of snow deposited in successive winters. Each of the superimposed beds exhibits on its surface a kind of gray or yellowish crust, which is formed by the mixture with the snow of bits of stone, dust, and even the remains of insects; under this crust extends a thin layer of glazed ice, caused by the freezing of the water which had melted on the surface. The strata of the *névé*, being thus arranged one above the other like the beds in a calcareous rock, are, in proportion to their age and the weight that is laid upon them, all the more compact and ice-like in their texture. In many places these strata may be perceived at the edge of the *névé;* for wherever the rocks rise above the upper snow-limit a kind of cleft may be noticed in the *névé*, owing partly to the rending force exercised by the whole mass on the upper beds, and still more, perhaps, to the flowing of the water which trickles round the base of the rocks which are warmed by the sun.

Fig. 57.—Cornice of Snow.

Below the *névé*, which is, in fact, the reservoir in which the ice begins to form which afterwards is to feed the glacier, properly so called, the frozen masses continue to become gradually modified as regards their internal structure. It is very true that a great part of the ice which is melted by the rays of the sun, the rain, or the mild breath of warm winds, remains in a liquid state, and in the form of rivulets finds its way through the crevices of the glacier, and joins the stream which flows over the rocks below. But there is another agent at work as well as the sun in the process of melting the ice in the very heart of the layers. This agent is the pressure exercised by the upper masses on the ice lying beneath them.

Naturalists have, in fact, proved that the melting temperature of ice lowers forty-two ten-thousandths of a degree (Fahr.) for every *atmosphere** of pressure. At the foot of rapid slopes, where the enormous weight of the layers above compresses the ice with the force of a large number of atmospheres, the liquefying point of the mass is considerably lowered, a greater or less amount of latent heat is set free, and a portion of the ice must melt and pass into water. Thus, in consequence of this pressure, cells and liquid veins are here and there opened in the interior of the glacier, the mean heat of which is, however, only a mere fraction of

* A weight equivalent to that of a column of water of about 32 feet.

THE MER DE GLACE AND ITS AFFLUENTS.

Scale in Kilometres ($\frac{1}{112,000}$)

0 1 2 3 4 5 Kilomètres

a degree lower than the freezing-point. The protracted and numerous experiments of Agassiz have proved that in a hole sunk to a depth of 200 feet in solid ice the thermometer marked on the average 31° 24′ (Fahr.), and that only in winter, and quite exceptionally, the temperature was lowered to 28° 24′ (Fahr.); in the open air the cold was most intense. Owing, therefore, to the comparatively high temperature of the ice, small veins of water are formed which penetrate its entire mass. Nevertheless, the particles of ice which divide the thin films of water remain separate only for an instant; for even under a slight pressure, very much less than that which is brought to bear upon glaciers, two morsels of ice surrounded by water immediately approach one another, and unite to form a single lump. Even in warm water two pieces of ice which are melting continually strive to combine, and the isthmus which joins them forms and re-forms until the last solid particles have disappeared. This is the great fact which was discovered by Faraday, and brilliantly demonstrated by Tyndall, who has given it the name of *regelation.* This phenomenon takes place at every point in the thickness of the glacier. Particles of ice approach one another, and unite across the little veins of water which permeate it in every direction; fresh liquid films are formed under the pressure above; fresh unions take place between the divided morsels of ice; and, by this continual process of change, the air contained in the mass of that which once was snow is gradually expelled. Thus it happens that the whole mass ultimately assumes an almost perfect transparency and a beautiful azure colour. It is, however, the case every winter that the clefts on the surface of the glaciers are filled up with fresh masses of snow. These new layers, to which an intermixture of air-bubbles gives a whitish tint, are dragged and thrown forward by the general movement. In several glaciers, where mighty *crevasses* disclose the internal structure of the whole mass, it is wonderful to see the alternate stratifications of gray snow and the blue belts of ice, just like the beds of a formation of rocks. On high elevations, *névé* and glacier are intermingled together. In climbing Monte Rosa, Zumstein saw, down in a *crevasse* of *névé,* real glacier ice, at a height of 13,989 feet, less than 1,300 feet below the summit.

Fig. 58.—Internal Banded Structure of Ice.

Nevertheless, whatever may be the modifications which the snow undergoes, it is a matter of fact that, even in the lower parts of glaciers, granules are found similar to those of the *névé,* only these grains have become transparent and free of air-bubbles, and in their long course towards the valleys have considerably increased in size. Some of them are as large as a chestnut, or even a hen's egg. These granules of ice are sometimes very irregular in shape, owing to the enormous pressure to which they have been subjected, sometimes in one direction, and sometimes another; but the phenomena of polarization which they present to the light prove that they are really crystals, and the whole glacier is an accumulation of granules confusedly packed together. From the moment when the snowflakes fall in the shape of needles and stars, to the time when they are reared up in blue walls, it never ceases, under all its various aspects, to retain a crystalline character.

The snows which are thus transformed into ice by the effects of pressure form the enormous masses which cover the mountain sides and fill up whole valleys. Some of these glaciers—those of the Pyrenees, for instance—only extend over the

upper slopes of the mountain, and do not descend through the gorges as far as the cultivated grounds at its base. These are the glaciers which Saussure calls *secondary* or *summit glaciers.* There are other fields of ice which also take their rise on lofty peaks, and, flowing out into the mountain amphitheatres, make their way into the lower valleys, uniting, on each side of their beds, with the ice of other tributary gorges; these are glaciers of the first order. There are some which extend to a length of 12, 18, or 30 miles, and attain a thickness of several hundred yards. These are easy to class; but in nature the transitions are so gradual that, as regards the greater number of glaciers, it is impossible to point out precisely in which category they ought to be classed. The distinction established by geologists is purely artificial.

CHAPTER XXXI.

MOVEMENT OF GLACIERS.—EXPERIMENTS AND THEORIES.—CONVEXITY OF THE CENTRAL PART OF A GLACIER.—ITS SUCCESSIVE WINDINGS.—FRICTION OF THE ICE AGAINST THE BOTTOM AND SIDES OF THE BED.—THE GLACIER GAUGE.—INCLINATION OF THE GLACIER BED.

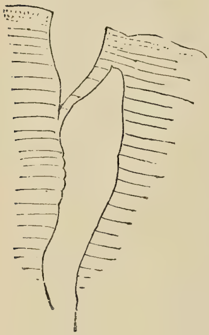
THE Alpine mountaineers, from time immemorial, have been aware of the fact that glaciers move onwards, and convey masses of rock from the mountain summits down into the valleys. At the end of the sixteenth century Simmler announced this marvellous fact, and other *savants* repeated it after him; but it was not generally known to science until the end of the last century, after the publication of Horace de Saussure's travels. This traveller, one of the first of that generation of energetic men who knew well how to combine scientific inquiry with skill, strength, and endurance, and could also both hit upon and unravel the mysteries of nature, verified the movement of glaciers, and attempted to propound a theory for it. He was, however, content with stating his ideas in a general way, without making any direct experiments to verify them.

Such experiments were first made in 1827 by Hugi, who had a little hut built on the glacier Unteraar, at the foot of the promontory of Abschwung. In 1830, the hut was 110 yards lower down; by 1836 it had travelled 780 yards; by 1841 it had reached a distance of 1,561 yards from its first position; its movement, therefore, had been at the rate of 112 yards a year. Since that date, a great number of experiments of the same kind have been made by other explorers. The measurements made so carefully by Agassiz on the upper tributaries of the same glacier, the Aar, the Finsteraar, and the Lauteraar, have proved that the two masses have shifted their places, one from 52 to 89 yards, the other from 34 to 81 yards each year, according to the various positions of the measurement-marks on the surface of the glacier. The motion was ascertained to be the more rapid in proportion as the marks were nearer the central portion of the field of ice. Thus this important fact was brought to light, that the mass of the glacier occupying the centre of the bed descends more quickly than the portion situated in the vicinity of the two sides. Henceforth the fact was recognised that, without any exaggeration of language, a glacier might be literally assimilated to a river. This, however, is an idea that had already been suggested by M. Rendu, an excellent observer of the mountains of Savoy. In a work on glaciers, published in 1841, he stated that there was a perfect resemblance between the Mer-de-Glace, in Savoy, and a river, and that it would be impossible to point out any phenomenon in any of the streams which might not be found in the other.

To what cause, therefore, are we to attribute this gradual descent of the river of ice in its rocky bed? At all events, it is certain that it is not a mere sliding of the mass over its lubricated bed, for it has been several times proved that above the zone in which the mean temperature of the ground is below the freezing-point—that is, at about the height of 6,600 feet in the Central Alps—the layers of the glacier are frozen to the ground, and cannot detach themselves from it by the mere force of gravity. On their lower surface they melt but slowly, except at the spot where the rivulet flows which gathers all the surface water sinking through the *crevasses.* There are also instances of a stream running by the side of a glacier from the *névé* to the terminal *moraines* without being able to penetrate the solid wall of ice adhering to its bed of rocks.

Since the investigations and experiments of Tyndall, it has become more than probable that the real cause of the onward motion of rivers of ice must be sought for in the formation of innumerable fissures, and in the reconstitution of all the broken fragments into a fresh mass. Regelation is taking place in every part of the glacier at once, and, as may easily be understood, the particles of ice compressed by the masses above them must always move in the direction of the slope when they shift their position in order to coalesce anew. This descending movement and the junction of the particles are taking place at the same time as regards millions and millions of broken granules, and from this very cause the whole body of the glacier descends in the gorge which serves as its bed. Under the pressure of the enormous weight which pushes it forward, the ice ultimately becomes so moulded as to fit perfectly into its channel of rocks, just as if it were a pasty mass. If the gorge becomes narrow, the glacier assumes a more elongated shape in order to make its way into the defile; if the mountain sides widen out in a basin, the glacier spreads out like a lake in the broad hollow. This remarkable plasticity of the ice under pressure has caused several distinguished natural philosophers (as James Forbes) to believe that the frozen mass, although so brittle, is of a viscous nature, and flows in the same way as treacle and honey. At the same time the frozen mass does not necessarily fit always exactly into its mould. Certain Alpine valleys forming the beds of ancient glaciers many miles long and hundreds of feet thick present fissures in their lowest depths, into which the ice has never penetrated. Such is the Via Mala, above which flowed the great glacier of the Rhine without ever penetrating to its deepest and narrowest gorges. Recently also, before the retreat of the Rosenlaui glacier, beneath the blue crystalline mass was distinctly visible a narrow ravine, through which a mountain stream flowed without hindrance.

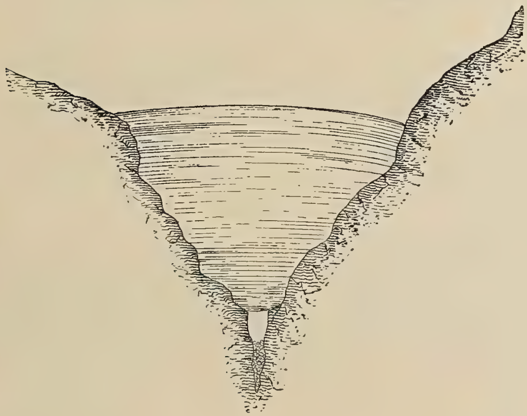
Fig. 59.—Plastic Property of the Névés.



Spring-time is the season in which the river of ice descends towards the valley with the greatest rapidity. Then the phenomena of liquefaction and regelation take place with the greatest frequency on the elevated *névé.* Innumerable rivulets of water, set free from their icy prison, widen the *crevasses* and lubricate the slopes on which the solid river has to glide slowly down. The blocks of ice, glued to the sides of their bed by the frosts of winter, regain their liberty. It is probable that in summer the progress of a glacier is at least double as fast as it is during the cold season. Thus, according to Tyndall, the progress of the Mer-de-Glace, near

Montanvers, is on the average about 13 inches a day in winter, and more than 24½ inches a day in the summer; but, between the extreme rates of speed, the difference is much more considerable. Every variation of temperature, however, makes itself felt in the progress of the glacier, and although experiments do not all agree on this point, it is probable that at sunset the glacier slackens its course, and accelerates it again when the luminary reappears above the ridges of the mountains; in the depths, as on the surface, the sun imparts life and animation. As soon as the early rays of daybreak have lighted up the glacier, its very nature seems altered. Just as in the adjoining forest, the field of ice is harmonious with a thousand small yet joyous sounds; the little drops, falling on the projection in the *crevasses*, tinkle as they are broken up; the gradually forming rivulet murmurs on its way; the slopes of gravel crumble down into the *crevasses;* and here and there some block, uncemented from its icy pedestal, roars as it rolls down the incline. All these voices of the glacier gain strength as the sun gets higher in the horizon; but if a

Fig. 60.—Passage of a Glacier over a Narrow Gorge.



thick cloud suddenly interrupts the solar rays, silence is gradually re-established and the glacier waits for the return of the sun ere it resumes its song. The enormous ice-river seems endowed with vitality; so much so that some enthusiastic *savants*, as Hugi, have seriously asked the question, whether the monster did not possess a soul? Numbers of mountaineers, in all their simplicity of mind, fully believe it.

Just as in liquid rivers, a bulging of the central portion of the glacier corresponds in general to the highest rate of speed in the moving mass. The convexity of the surface of the icy stream must not be attributed to an afflux of the whole body towards the middle; the cause is, perhaps, the fact that the central parts, being animated by a more rapid motion, have not had sufficient time to evaporate and melt in as large quantities as those at the sides, which are slower in their progress and more intersected with *crevasses*. Sometimes, however, it is the case that the glacier exhibits an exactly contrary outline, and is hollowed out like a gutter in the central part. This happens when immense *moraines* cover a broad

surface of the ice on each side, and hinder their melting. An instance of this fact is to be found in the glacier of Vernagt, in the Œtzthal.

Not only does the river of ice act exactly like a liquid watercourse by its waves rolling on with much more rapidity in the central portion than at the edges, but, similarly to all other rivers, it assumes the greater amount of force in its current at the convex side of its successive windings. Theory would have beforehand

Fig. 61.—Windings of a Glacier.

presumed this fact, which, however, the experiments of Tyndall in 1857 have indubitably established. His measurements, very carefully made across the various curves of the Mer-de-Glace, have proved that the thread of the current shifts its position alternately to the right and left of the medial line, and approaches each of the sides in turn, sometimes one, sometimes the other. Thus the axis of movement follows an undulating line, the windings of which are more decided even than

Fig. 62.—Crevasse of the Schwarzenberg Glacier; after Viollet-le-Duc.

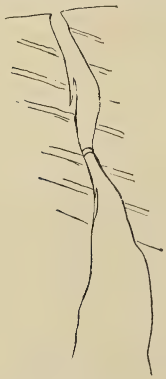
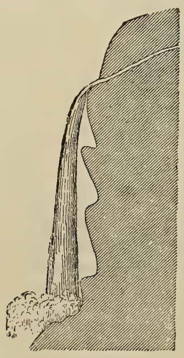


Fig. 63.—Cascade of Glacier.

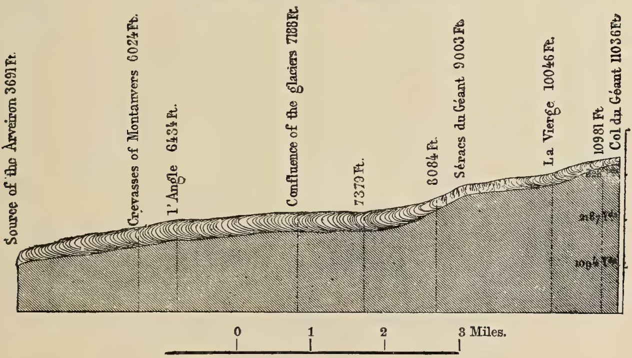


those of the gorge of the glacier. The ideal progress of the frozen river is represented by the above illustration (Fig. 61), which would apply equally to the current of a liquid river. The observations made by M. Heim on the Hüfi glacier, showed for the central part a velocity three or four times greater than that of the sides.

The same cause which impedes the motion of a glacier at the edge—that is, the friction of the sliding mass against the rocks—equally diminishes the rapidity of

its current along its bed. In this point, also, the action of a glacier is perfectly analagous to that of a river moving at a slow pace. Forbes and M. Martins have proved this on the Mer-de-Glace and the Faulhorn, by experiments which Tyndall has since renewed at the risk of his life. Descending the sides of a precipice 137 feet in depth, opening between the rocks and the glaciers of the Tacul (Mont Blanc), he succeeded in fixing three pegs at the summit, at the middle, and at the base of the vertical wall of ice, so that he should be able to measure their respective rates of progress two days afterwards. The upper peg had advanced 5½ inches in the twenty-four hours; the middle one, fixed 36 feet above the bottom, had only moved onwards 4 inches in the same space of time; lastly, the lower mark, fixed more than a yard above the rocky bed of the glacier, had only progressed at the rate of 2½ inches a day. Added to this, in certain places the cascades of surface water cut out ledges resembling steps in the sides of the *crevasses*, which, as it were, bring before the eye the superior rapidity of the upper layers of the ice. The water falls, in the first place, on some projection, which it hollows out in the shape of a basin; but, in consequence of the onward motion of the glacier, the liquid

Fig. 64.—SLOPE OF THE MER-DE-GLACE.



column soon gets beyond the first projection, and drops down upon a second, and then upon a third; it thus forms the succession of steps resulting from the rapid advance of the ridge of ice from which the cascade descends. For the same reason the walls of the *crevasses* are always inclined in the same direction as the movement, as shown by the accompanying figure, representing the *crevasse* of the Schwarzenberg glacier, studied by Viollet le Duc.

A comparison of the experiments which have been made up to the present time with regard to the speed of various glaciers, warrants us also in thinking that the advance of the current is accelerated in proportion to the declivity of the slope; only, as M. Desor points out, the volume of the matter in motion being by far the principal element in the increase of speed of the whole mass, the result is that small glaciers at a very steep slope descend more slowly than larger ice-rivers on a slight declivity.

Thus the advance of a glacier presents very considerable differences in the rate of progress, according to the importance of the total mass in width and depth, its proximity either to the edges or the bottom, the winding of the sides, the degree

of slope, the expansions and contractions of its bed of rocks, the state of the temperature, and the various seasons of the year. It is, therefore, impossible to estimate the mean rate of speed of a river of ice by taking as our basis a series of isolated observations; we must, on the contrary, study the movement of the ice in every part of its bed, take account of every cause of acceleration and delay, and, if we may so speak, gauge the glacier as we should gauge a river of running water.

The movement of the ice, like that of rivers, takes place over slopes of the most varied character. The Mer-de-Glace, at Chamounix, is inclined on the average 5 or 6 degrees, but at many points in its course it presents a much more considerable declivity. Some glaciers, half suspended on the mountain sides, have an inclination of 25, 30, and even 50 degrees, and yet it is but seldom that the masses lying on these formidable slopes take to sliding on their bases so as to fall down like avalanches into the valley beneath. They descend gradually and slowly, like other glaciers which are almost horizontal in appearance, and run down gorges the slope of which does not attain to 3 degrees. The immense glacier of Aletsch is inclined only 4 degrees; those of the Œtzthal, on the average, 5 or 6 degrees; those of Monte Rosa and the northern sides of the Finsteraarhorn group are much more sloping, and incline 10, 15, and 20 degrees, or, as the upper glacier of Grindelwald, as much as 27 degrees.

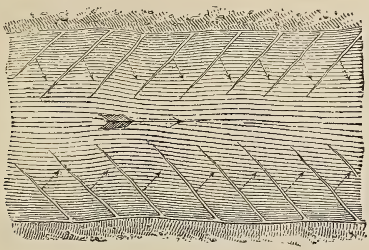
CHAPTER XXXII.

MARGINAL, TRANSVERSAL, AND LONGITUDINAL CREVASSES.—SÉRACS.—MOULINS.—BRIDGES OF SNOW.—VEINS OF FRESH ICE.—SURFACE-STREAMS ON GLACIERS.—GOUILLES.—LAKES AND INUNDATIONS.—DISCHARGING CHANNELS.

THE whole mass of the glacier does not advance in a perfectly continuous way, as a stream of water would do; the layers of ice could not follow all the windings of the gorge and adapt themselves to all the inequalities of the bottom without some extent of fracture. Thus fissures, or *crevasses*, are produced in the thickness of the apparently motionless river, and sometimes give to the latter a most uneven surface.

Most of the *crevasses* in a glacier are found near the sides, and principally at the convexity of the bends, on account of the inequality of tension to which the layers of moving ice are liable at these spots. The layers which are the closest to

Fig. 65.—Marginal Crevasses in a Glacier.

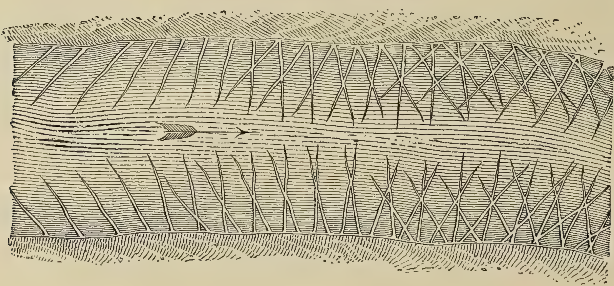


the bank are retarded by the friction of the rocks, whilst farther into the stream the rapidity of the current of ice increases with its distance from the edge. This difference in the rate of speed results in a greater tension of the mass in the direction of the movement, and in consequence the ice on the edge has to resist a tractile force, acting, as Sonklar and Hopkins have proved, in a line inclined 45 degrees to the bank. Finally, the ice gives way to the power which draws it; it is rent open; and, as the laws of mechanics dictate, the marginal *crevasses* are produced perpendicularly to the force of traction. The principal force of the movement being exerted in the direction of a line tending up stream at an angle of 45 degrees to the bank, the fissures in general form at a similar angle to the

bank, and also tend up stream; they are consequently transverse to the course of the current; therefore, at first sight of these clefts, we should be inclined to say that the glacier advanced with more rapidity near its edges; indeed, almost all the first observers were deceived on this point.

The marginal *crevasses,* however, do not retain their early inclination of 45 degrees to the bank of the glacier, the motion of the current being more rapid towards the centre than near the edges; the fissure turns round slowly, like the spoke of a wheel, and becomes less and less obliquely sloped towards the bank; sooner or later it becomes perpendicular to it, and then inclines gradually in the direction of the descent, describing a more and more acute angle. But whilst this first *crevasse* is thus bending round in a down-stream direction, first one and then another marginal cleft may be produced in the ice, subjected as it is to the tractile force of the moving mass; and these planes of rupture are at first likewise inclined at an angle of 45 degrees in an up-stream direction, and afterwards bend round in the direction of the current. This sometimes results in an intersection of cracks, which transform the lateral portions of the glacier into a perfect labyrinth of

Fig. 66.—Intersecting Crevasses.



crevasses, in which it becomes difficult to recognise the regular order of the successive phenomena.

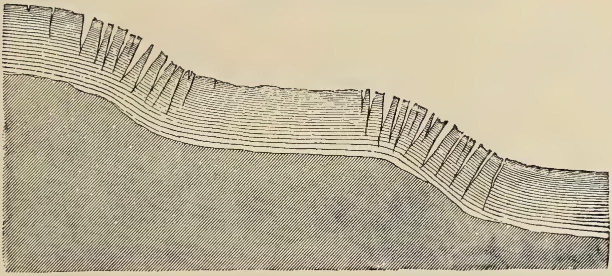
The *crevasses* which are formed from bank to bank across the field of the glacier are caused principally by the inequalities of its bed. In places where the declivity becomes more abrupt, the ice, being unable to accommodate itself to this fresh slope, cracks right across, and by a series of fissures spreads out its surface to form an inclination similar to that of the bed which it covers; the clefts, it must be understood, are all the more numerous and wider as the fall is more sudden.

Below rapids and cataracts, rivers spread out into large and smooth sheets of water; a similar phenomenon takes place in glaciers below any very steep slopes. When they reach these more level beds, the masses which have been separated by the fissures again come close together, and pressing one against the other, resume the uniformity of surface. If a second sudden fall of the bed gives a more rapid movement to the river of ice, it will a second time descend in a cascade of *crevasses,* which will become obliterated on the mass reaching some less important declivity. The lower glacier of Grindelwald presents a striking instance (first pointed out by Tyndall) of this succession of *crevasses* and level fields of ice. From the tops of a headland a clear idea may be formed of the general aspect of the glacier, and of its alternately dislocated and compressed masses. The kind of semicircular curve

which the transversal *crevasse* produces by uniting with the marginal fissures very often deceives the sight, and would lead us to believe that the force of the current was more especially exerted at the edges, if reason and experience did not teach us precisely the contrary. It must also be added that these cross *crevasses* are generally slightly curved in the direction of the motion.

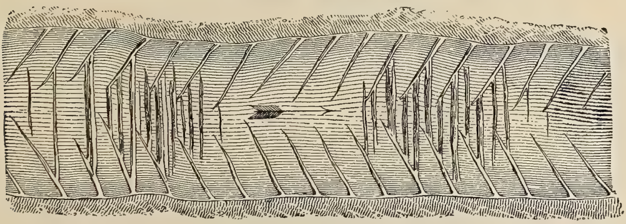
In a similar way to the transversal clefts, those which extend in a longitudinal direction are likewise owing to the direction of the bed. In every part of the bed

Fig. 67.—Transverse Crevasses, seen in Profile.



of the stream where the longitudinal risings, similar to the shallows of a river, force the ice to bend over laterally both right and left, the latter must form parallel *crevasses*, and these fissures cannot close up until they have descended below the obstacle. Added to this, there are often abrupt rises and falls in the bed which are so constituted as to cause the simultaneous rupture of the ice in both a longitudinal and transverse direction, and, consequently, the field of ice is traversed by

Fig. 68.—Transverse Crevasses seen in Plan.



crevasses which are semicircular or bent round in various directions. In this way the appearance of the surface often reveals the irregularities of the bed.

Lastly, glaciers also exhibit radiated *crevasses*, especially at their extremities, when the base extends widely into the lower gorges. The pressure of the masses descending from the mountain heights compels the ice down below to spread out laterally, and, in consequence, over the whole slope of the glacier there is a formation of radiating *crevasses*, sometimes exhibiting the regular arrangement of the ribs of a fan. According to various slopes and the inequalities in its beds, the ice presents the very greatest diversity in its lines of fracture. These clefts form a

perfect labyrinth on the surface of all glaciers which possess numerous tributaries, and move along a winding and occasionally contracted bed.

Anyone who happens to be on a glacier at a time when a *crevasse* is developed cannot possibly resist a certain feeling of dread The monstrous river suddenly takes to cracking and groaning ; dull reports, caused by sudden ruptures, are every moment heard in the interior of the mass; and a prolonged grating sound, like that made by glass when slit by a diamond, announces the gradual increase of the cleft. Nevertheless, when all the voices of the glacier are hushed, it is sometimes

Fig. 69.—Longitudinal Crevasses, seen in Plan.

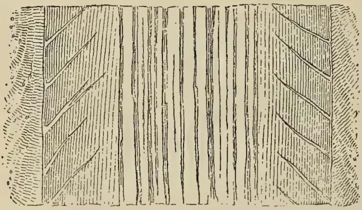
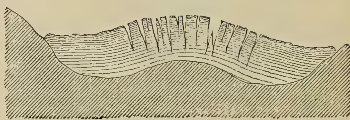


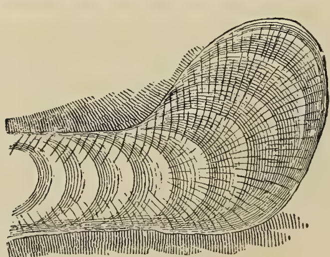
Fig. 70.—Longitudinal Crevasses, seen in Profile.



quite in vain that we seek for the crack, on account of its extreme fineness. The *crevasse* widens very slowly, and it takes days, and sometimes even weeks, before it becomes one of those formidable chasms which gash the surface of the glacier.

When the *crevasses* have arrived at their full development, they exhibit a most striking spectacle. The two bluish walls sink down into darkness which is unfathomable by the eye; stones, falling from the surface, bound over the projections, and awaken dull echoes as they are lost in the obscurity; a vague murmur of running water ascends from the depths, and sometimes sharp gusts of cold and

Fig. 71.—Frontal or Terminal Crevasses; after Tyndall.



biting air issue out from the mouth of the abyss. While leaning over the brink of the gaping chasm one feels a kind of dread, as if the noises and darkness of the gulf beneath belonged to some new world, full of mystery and horror.

When the *crevasses* are numerous, and intersect one another in various directions, it often happens that masses which are thus isolated, and are also of a more compact nature, resist for a longer period the action of the sun and wind. In consequence of all these inequalities, and doubtless also on account of the difference in pressure operating at the base, the ice, in some spots, assumes the

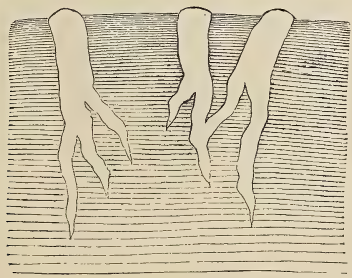
most picturesque and fantastic shapes. Sometimes these blocks resemble knights clad in their armour, sometimes strange animals, broken statues, pointed clock-turrets, or ruined colonnades. Tourists ask with astonishment how it is that nature, by nothing but the slow operations of the forces of gravity and pressure, the winds, and solar rays, is able to carve out the ice into groups so remarkable both for their regularity and grotesqueness. The tower-shaped forms which crown some of the abrupt falls of the glaciers have received from the Swiss mountaineers

Fig. 72.—Superficial Torrents of a Glacier; after Tyndall.

the name of *séracs*; a term which reminds one of the *sérets*—cheeses which spilt up into small cubical pieces.

In the lower portion of the glacier surface the walls and pillars which are divided from one another by fissures seldom show perpendicular sides. Their faces which are turned towards the south become wasted and worn away, and thus assume the appearance of enormous congealed waves. When the great river has this furrowed surface, it really becomes a "sea of ice." Owing to the more rapid motion of the upper layers, it generally happens that the ice-waves present their

Fig. 73.—Chasms in a Glacier filled with Snow; after Tyndall.



steepest face in a downward direction, and are less abrupt looking upwards; when this latter side is also that which fronts the south, it ultimately becomes a more or less inclined slope.

In some places the fields of ice are also hollowed out into perpendicular wells, known under the name of *moulins* (mills), on account of the roaring noise of the water which is engulfed in them. The formation of these abysses may be very simply explained. The drops of water melting on the surface combine into slender rivulets, which form tributaries of a more considerable stream, which winds along its bed of ice. When this surface-stream finds in its path some gaping *crevasse*, it sinks into it, and immediately disappears in the depths below; but it often meets with some crack crossing the field of ice which is almost invisible. The water

makes its way into this crack like a blade of steel, and gradually widening it, is swallowed up between the separated sides of the crevice. Soon the incessant labour of the water succeeds in hollowing out a complete well, which sinks down to the stream hidden under the glacier. This *moulin* shifts its position with the whole mass surrounding it; but at the spot where it was formed a new cleft is produced in the glacier by the same causes as the first, and the little stream gradually bores out in it a second deep hole. Thus, on the same line, several circular wells are hollowed out, the most elevated of which is the funnel of a cataract, whilst each of the others has, in its turn, been deserted by the water that formed it. *Moulins*, like *crevasses*, are sometimes made use of by observers who wish to measure approximately the thickness of a glacier, either by noticing the duration of the fall of a stone, or by employing a sounding-line. In this way the thickness of some of the Alpine glaciers has been estimated at 800, 1,000, and even 1,650 feet.

In winter both *moulins* and *crevasses* are either altogether or in part filled with snow, which makes its way into the interstices of the ice, and moulds itself to fit them, just like lava flowing into the clefts of a rock. When the mass of snow does not descend right down into the depths of the *crevasse*, and only manages to unite the two edges of it, it forms over the chasm a kind of bridge, which a mere shaking of the glacier will sometimes suffice to hurl down. These unsupported beds of snow constitute the greatest danger for travellers who venture on to glaciers. There is no visible indication to point out the vast gulf below, which descends perhaps to a depth of hundreds of yards. The field of snow is level, and seems to invite one to walk over it; but if an incautious traveller sets his foot upon the snow spread over the chasm before he has carefully sounded it, the mass may suddenly give way, carrying with it the unfortunate individual whom it has failed to support. The greater part of the accidents which happen every year upon the mountains are owing to the fall of these snow-bridges across the chasms of the glaciers.

Generally the snow in the *crevasses* is the first to melt and fall down in the hot season, on account of its position being exactly in the spot where the surface-water chiefly flows; but it often happens that, in consequence of the motion of the glacier, some of these chasms filled with snow do not fall in the way of any of the rivulets running over the surface. In this case the snow gradually hardens, and ultimately becomes changed into ice, under the pressure of the layers surrounding it. This recently-formed ice is at first distinguished by its whitish shade, its granular texture, and a great abundance of air-bubbles. Thanks to its colour, it resists the melting influences longer than the surface round it, and may sometimes be distinguished from a considerable distance by a kind of cone which shows itself above the field of ice. It also sometimes happens that similar white veins of transformed snow fill up all the windings of the beds of the temporary streams which are hollowed out in the thickness of the glaciers. In the tributaries of the Mer-de-Glace, Tyndall remarked several of these moulds of former streams.

Lakes, as well as miniature rivers, fill up the depressions in some glaciers. Sometimes they are mere ponds, or *gouilles*, formed in some unfinished *crevasse;* in other cases they are like wells, and sink down to the rocks in the bed of the glacier. In some localities, the surface water, finding no outlet to the valley beneath through the solid mass which covers the ground, collects in a hollow between the field of ice and the sides of the rock. Cliffs of a deep blue tinge, with snow-capped summits, border the lake-like sheet of water, which is still bluer than

the ice itself. Sometimes blocks, separated by fissures from the masses above, break away with a crash, and, as they plunge into the water, raise high waves, which spread rapidly across the basin, and breaking on the opposite cliff-like shore, describe on the surface of the lake a graceful network of interwoven ripples. Little islets of still unmelted ice float here and there under the impulse of the wind, which blows hard through the mountain gorges. There are few sights more charming among the lofty mountains than these little lakes surrounded by snow, like sapphires set in silver.

The greater part of these glacier lakes are formed by the waters of a lateral gorge which is penned up by a natural barrier of ice. This water, proceeding from the upper snows, or from secondary glaciers, which do not descend to any great distance from the summit, finds its passage obstructed by the body of the principal

Fig. 74.—The Glacier of Giétroz in 1818.

glacier pushing on its way towards the plain, and thus arrested in its course, forms elongated lakes, the lower extremity of which abuts on the barrier of ice. Some of these lakes are of a permanent character, and some merely temporary. The former, occupying deep depressions hollowed out in the rock itself, cannot possibly flow down into the valley; the latter, being only kept back by ramparts of ice, sometimes melt, and sometimes throw down the obstacle which opposes their outlet. As soon as the icy wall yields to the pressure of the water, the latter pours out in a sudden and mighty rush, the lake is changed into a torrent, or plunges in furious cataracts down into the gorges beneath, and in a few hours discharges the liquid mass which had been accumulating during a long period of years, or perhaps centuries.

The history of Alpine inundations is full of accidents of this kind. Thus it

was that the Lake of Rofen, which had been forming for fourteen days by the encroachment of the glacier of Vernagt, in the Œtzthal, suddenly opened for itself a passage. Within an hour's time its basin was completely emptied, the valley of Sulden was devastated by blocks of rock and sand, and the Inn itself, swollen by the sudden flood, laid waste its banks as far as its confluence with the Danube, The temporary torrent which the inundation threw into the Inn was not less than three millions of cubic yards of water, at the rate of 953 yards a second. This, however, is a trifling matter compared with the mass of water that must have rolled down if the Lake of Rofen had found no means of escape for several years.

The lower glacier of Giétroz, which flows, at a height of 6,036 feet, into the Valley of Bagnes, not far from the Monte Rosa group, had in the same way several times dammed up the passage of the stream of the Dranse, a tributary of the Rhone; but in a general way the barrier of ice melted at the beginning of spring, and no catastrophe had to be deplored. In 1818 the case was different; the mass of ice descending from the upper *névés* was so considerable that the Dranse, being unable to flow through it, was driven back, and necessarily changed into a lake above the obstacle. At the beginning of May, the dam of ice, which was about 660 feet in length between the two mountains, was not less than 420 feet high, and more than 30,000 feet in width at its base. The lake, more than half a mile in width, was incessantly increasing, and its depth, which in certain spots reached 260 feet, augmented, on the average, 3 feet a day. Its contents might be estimated at more than six millions and a half of cubic yards. The danger was a terrible one to the inhabitants of the valley below. Under the direction of Venetz, the engineer, they set to work to dig a draining channel across the rampart of ice, and succeeded, in fact, in gradually lowering the level of the water of the lake. On the 16th of June, at four o'clock in the afternoon, the barrier gave way; the pent-up water, driving before it both ice and rocks, suddenly sprang into the valley with such rapidity that in twenty minutes the whole basin was empty. This formidable cataract swept away woods and *châlets*, and laying bare the rocks and carrying away the very meadows, emptied itself into the plain like a mingled avalanche of water, trees, and *débris*, 300 feet in height, and preceded by a black and thick vapour, like the smoke of a conflagration. The havoc was very considerable, not only in the valley of the Dranse, but also on the banks of the Rhone. In order to avoid the return of a similar disaster, the draining channel of the Dranse was cut out afresh every year beneath the glacier. This operation gave an opportunity of ascertaining the adhesion of the ice to the bed over which it flows, even at an altitude comparatively not very considerable. The Lake of Möril, which is penned up by the enormous barrier of the glacier of Aletsch, also communicates with the valley of the Rhone by a draining channel, which carries off the overflow of its waters.

CHAPTER XXXIII.

DÉBRIS LYING ON THE SURFACE OF THE GLACIER.—HOLES IN THE SURFACE.—GLACIAL TABLES.—MORAINES; LATERAL, MEDIAL, AND FRONTAL.—RIBBONS OF MUD.—MEASUREMENT OF THE SPEED OF GLACIERS.—ABLATION.—SUB-GLACIARY STREAMS.—TERMINAL ARCHES.—CONTRAST BETWEEN THE GLACIER ICE AND THE SURROUNDING VEGETATION.

LIKE all other rivers, the glacier bears along with it a certain quantity of alluvium, which it ultimately deposits at the end of its course, after a lapse of time which varies in length. The moving surface of the ice receives all the *débris* which has been detached from the bare cliffs by the action of thaw, rain, wind, or other meteoric agents, all the avalanches of stones which come down with the snow from the ravines above, all the fragments of those immense ruins which tower up in the form of needle-shaped peaks or jagged ridges. Glaciers which are shut in between schistose mountains, the sides of which easily crumble away, are often quite black with *débris;* others on the contrary, which are commanded by more compact rocks, or long snow-clad slopes, retain partially the whiteness of their surface; but all carry with them along one or both of their banks a certain quantity of rocks and stones belonging to all the geological formations of the basin. Borne along by the ice, this rocky rubbish commences but slowly its journey towards the sea, where it arrives, sooner or later, in the form of sand or mud.

Some parts of the *débris* which fall from the cliffs into the bed of the glacier gradually make a hole for themselves and disappear in the depth below; others, on the contrary, seem to rise in consequence of the gradual sinking of the surrounding surface. In fact, if a small pebble of a dark colour lies during the day on a bed of ice, it will rapidly absorb the solar rays, and, melting the particles on which it rests, will descend slowly into the little well which it bores by the action of its own heat; sometimes the disappearance of all the *débris* gives the surface of the glacier an appearance like an immense sieve. The result is, however, quite different when, instead of isolated stones, great masses of rock roll down upon the glacier in a body. These large heaps are, it is true, warmed on their surface by the solar rays, but at the same time they protect the space of ice that they cover against the heat. Therefore, all round them, the surface-layers of the glacier gradually melt and evaporate, whilst these lumps retain their original height, and seem even to increase, like volcanic cones. Finally, however, the base of the cone of ice which bears up these heaps of rock gradually melts away, the *débris* slide down on the slope which has become too steep to keep them up, and soon after the hillock sinks and disappears.

A phenomenon of the same nature takes place when a large block of stone—such as a slab of schist or granite—covers the ice and shelters it from the rays of the sun. The surrounding surface slowly sinks, leaving underneath the slab of stone a pillar like a marble column crowned with a heavy capital. However, on the glaciers of the Alps and other mountains of the temperate zone, these slabs of stone never lie horizontally on their pedestals; being exposed obliquely to the southern sun, they receive the most heat from this quarter, and they warm the corresponding side of the pillar supporting them. Simultaneously the solar rays melt away some of the lower portion of the pillar of ice, so that the slab gradually bends over towards the south. As a matter of theory, as Tyndall says, these slabs ought to turn, like a kind of sun-dial, simultaneously with the sun, and thus mark every hour of the day; but this daily rotation is too slight to be perceptible, and the general result is all that can be ascertained, that is, the inclination of the stones towards the south. Ultimately, the inclination becomes so rapid that the stone slab falls from the top of its column, and immediately after begins to form a second; thus pillar follows pillar under the rocky masses borne along by the ice. Some of these natural *dolmens* have been noticed having an area of twenty-four to thirty square yards. Among the variously-shaped rocks which are carried along by the glacier, some attain a bulk of thousands of cubic yards. The rock called Blaustein, which we now see in the valley of Saas, is a mass of serpentine more than 10,000 cubic yards in bulk, which, in 1740, was still upon the glacier of Mattmark.

Fig. 75.—Glacier-table; after Tyndall.

It is perfectly natural that at first all the rocks and *débris* which have rolled down should lie at the foot of the high walls of rock which overlook the glacier. These heaps constitute the lateral *moraines*, or ranges of stone, running in a line on each side of the bed of ice, like roughly made ramparts, and participating in the movement of the frozen river. Sometimes, however, these broken rocks are buried in the hollows which open either at the base of the mountain, or at a little distance from it in the heart of the glacier itself. The *moraine* is then concealed in the midst of the glacier, but embraced as it is by the whole moving mass of ice, it does not fail to descend towards the valley; and often, when the upper layers are melted, it again makes its appearance above the surface and overtops the level of the glacier. Some of these lateral *moraines* rise to a height of 70 or 80 feet above the current. On the Murzoll, in the Austrian Alps, there are several which are more than 100 feet high.

Below the confluence of two glaciers, the *moraines* which skirt both sides of the base of the central promontory unite like the solid waves which bear them along, and thus form in the middle of the river of ice a third *moraine*, running parallel to those on the edges. If a third tributary glacier runs into the principal current, a second medial *moraine* is formed on the glacier, parallel to the first; finally, however great may be the number of the tributaries, each of them will unite one

GLACIERS OF GEISBERG

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of its lateral *moraines* to that of the principal glacier, so as to form another medial ridge of *débris*. By examining the surface of a glacier of regular development, such as the Mer-de-Glace, or the glaciers of Geisberg or Rothmoos, the number of its tributaries may be reckoned by the number of walls of *débris* which extend along the line of its current.

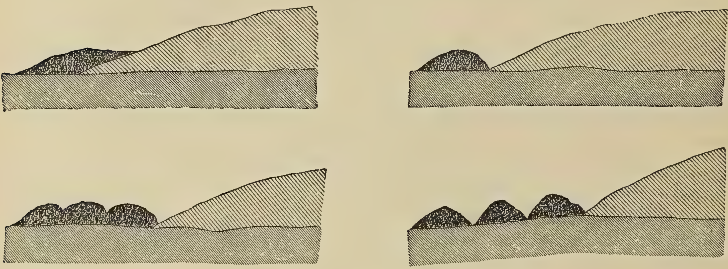
A number of these medial *moraines* disappear at their very source in the depths of the *crevasses*. They remain buried in the heart of the glacier until the layer above them is entirely melted, and then, after having traversed a greater or less distance, they reappear on the surface as if they had been upheaved by some great eruptive force. It is curious to notice how, at a distance of many hundreds of yards, or even some miles, the enormous alluvium of rocks retains its original direction. The rivers of ice poured out by the tributary into the common bed flow on side by side without mingling their masses; in the same way rivers, the waters of which differ in colour, like the Missouri and the Mississippi, roll on together in the same channel for a long time without intermixing their waves. The steep faces of the side glaciers sometimes exhibit most clearly the vertical line which separates the contiguous masses of two tributaries which have flowed in above.

After a long course of years, or even centuries, the masses of the lateral and medial *moraines* reach the lower extremity of the glacier, and fall one over the other down the slope of the valley. During a succession of ages, the stones which are too heavy to be carried away by the action of water are collected together in enormous heaps below the river of ice. These heaps constitute the great frontal *moraines* which obstruct the approach to so many glaciers, as these formidable slopes are sometimes hundreds of feet in height. These *moraines*, consisting of a vast rough alluvium, pushed on by the ice, make their way for a greater or less distance into the valleys, according to the pressure of the masses above. When the force of the latter increases, the accumulation of blocks moves onwards, and, in its irresistible progress, overwhelms plains, rocks, and torrents. On the other hand, when the glacier recedes, the enormous barrier in front of it remains isolated, like a rampart built up across the valley, and, higher up, the glacier constructs another frontal *moraine* with the *débris* it carries down with it. In several gorges, especially in that which extends below the glacier of the Rhone, and likewise in the New Zealand valley of Avoca, six or seven *moraines* in a line have thus been abandoned by the ice, the lower extremity of which has receded upwards. But if the frozen river recommences its gradual advance, then these heaps will be added to the other *débris*, and all these old *moraines* will unite in one gigantic moving rampart. In a similar manner, glaciers which have diminished in size, and have stranded their lateral *moraines* on the adjacent slopes, may, when they again increase, once more pick up these *débris*; like a flooded river carrying off the drifted wood left upon its banks, the river of ice may impel the mass of blocks a second stage towards the sea. When the glaciers have lost much of their thickness on the slopes, along their sides are visible parallel ridges marking the successive stages of their retreat. The lower part of the Bionnassay glacier is skirted by six such ramparts of coarse alluvial matter.

Fig. 76.—Lateral Moraines.

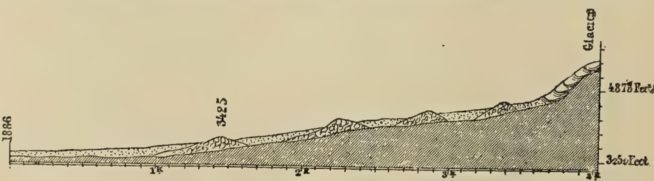
In addition to these various kinds of lateral and medial *moraines*, the surface of some glaciers exhibits concentric bands of mud and rubbish, arranged, in some cases, with the greatest regularity. The Mer-de-Glace, in the Mont Blanc group, is a remarkable instance of this singular distribution of these layers of mud on the glacier field. The first bands of mud appear below the great cataract of *séracs* which are found between the *névé* of the Col-du-Géant and the glacier proper. During the heat of summer, when the renewed activity of the glacier communicates a more rapid impetus to all the layers in motion, the fallen rubbish accumulates in

Figs. 77, 78, 79, 80.—Frontal or Terminal Moraines.



a circular rampart at the base of the escarpment, and then, carried away by the current of the river of ice, advances slowly in the rear of other ramparts which had fallen previously. Mud, dust, and fragments of every kind gradually fill up the furrows made between the raised barriers of ice; the latter gradually melt, and ultimately assume the same level as the general surface of the current, but the belts of brown or reddish mud still retain their ribbon-like arrangement, and, like the concentric undulations which form in smooth water, present at first an almost perfect semicircular curve. But at the contraction of the ravine at Trélaporte, where the whole river of ice is compressed and is compelled to pass through a narrow channel, the belts of mud are drawn out towards the centre on account of the increased rapidity of the movement which carries them along. These zones of mud, the curves of which are in a contrary direction to those of *crevasses*, may, therefore, be looked upon as regular floats, indicating the direction and exact progress of the current of ice. Perhaps, also, in each interval between the ribbon-like belts we ought to see the precise measure of the annual growth of the glacier, and the belts would resemble the rings of wood which trees produce every year, by

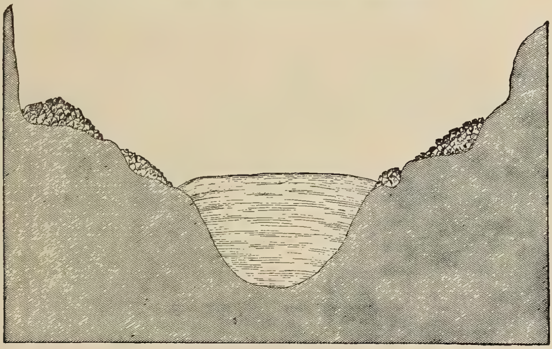
Fig. 81.—Profile of the Valley of Avoca, New Zealand; after Julius Haast.



which we are enabled to calculate the age of the trunks. If this were the case, the central part of the Mer-de-Glace would entirely pass away in about forty years, and the average rate of speed would be about 23½ inches a day, which agrees, in fact, with the actual measurements which have been made by various observers of the advance of the glacier.

When several generations of *savants* shall have followed up, one after the other, this kind of investigation, we shall perhaps learn the exact speed at which the stream of ice moves onward. This will be effected by dropping into the deep fractures on the highest point of the glacier various objects, which the mass will carry on with it down to the bottom of the gorge, and will ultimately leave bare at its terminal *moraine*. A ladder which Saussure left in 1788 at the foot of the Aiguille-Noire, when he ascended Mont Blanc, was found in 1832 at a distance of 4,757 yards below. The ladder had, therefore, descended during these forty-four years at an average annual speed of 108 yards, or nearly 11 inches a day. A knapsack which, in 1836, fell into a *crevasse* of the glacier of Talefre, travelled more rapidly than Saussure's ladder; it moved on at the rate of 140 yards a year, or

Fig. 82.—Lateral Moraines of Ablation.

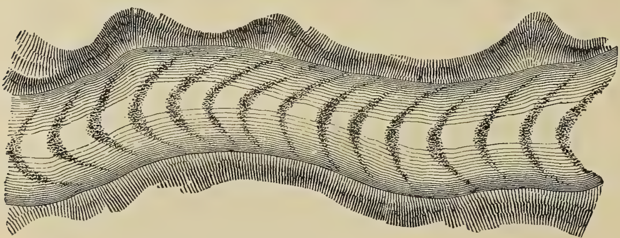


nearly 14 inches in the twenty-four hours. But all these observations fail in serving as exact measurements of the real speed of the *mass* of the glacier, for it would be necessary to know precisely if the foreign bodies which were carried along lay in the central part or on the edges of the icy current, in its very heart or in the vicinity of the bottom. However this may be, approximate calculations lead to the belief that the snow that falls on the Col-du-Géant takes about one hundred and twenty years ere it arrives, changed into ice, at the lower extremity of the Glacier des Bois.

Human remains, too, have unhappily served as means for estimating the rate of movement of the ice. In 1861, 1863, and 1865, the Glacier des Bossons has yielded up the relics of three guides who fell in 1820 into the first *crevasse* opening at the foot of Mont Blanc. These buried remains had, therefore, during a period of more than forty years, passed over a space of about three miles and three-quarters, descending at the rate of 160 to 170 yards each year. In the year 1860 a more slowly-moving glacier in the Austrian Alps, which flows in the Ahrenthal, threw out a well-preserved corpse, still clad in a dress the ancient fashion of which had been abandoned by the mountaineers for centuries.

Each glacier, taken as a whole, may be looked upon as forming *two* rivers, one of which takes years, or even a century, in descending from the summits into the valley, having assumed the shape of solid ice; the other flows down in a few days, and in the day-time assumes the appearance of a stream. In summer, the phenomenon which has been designated by the name of *ablation*—that is, the surface-melting of the ice—takes place rather rapidly. In the month of August, on the glaciers of the central Alps, the thickness of ice melted averages from 1 to $1\frac{1}{2}$ inch a day, and during a series of days which are favourable to the melting process, the layer of ice which changes into water is still more considerable. According to M. Desor, the mean *ablation* in a spot favourably situated in the middle of the Glacier de l'Unteraar rose to $2\frac{3}{4}$ inches a day during several months. On the Glacier du Gurgl (Œtzthal), not very far below the lower limit of the *névé*, Sonklar found, in the month of August, five surface-rivulets which together discharged $15\frac{3}{4}$ cubic yards of water a minute, 45 gallons a second; and on the great glaciers of the Swiss Alps, temporary watercourses must doubtless be formed of much greater importance. In autumn and winter the amount of *ablation* is diminished, but this phenomenon rarely ceases altogether, and in spots which receive the solar rays, or are touched by the warm mists of the plain, small rills of water hollow out a bed for

Fig. 83.—Ribbons of Mud, Mer-de-Glace; after Forbes.



themselves in the ice and among the *débris* of the *moraines*. M. Desor has estimated the mean *ablation* on the Swiss glaciers as amounting to 10 feet a year, or 0·3176 inch a day.

The thawed water which trickles over the surface of a glacier sinks into the *crevasses* and the *moulins*, and makes its way from fissure to fissure to the deepest recesses of the gorge, now filled up by the frozen river. Owing to its temperature being somewhat above freezing-point, the water, when collected in this hidden bed, and here and there mingled with the flow from springs, thaws a certain quantity of ice above its course, and thus opens out a free passage towards the valley. The stream which gushes forth at the base of every glacier represents, in its annual discharge, the whole of the snow which falls in the gorges and on the tributary escarpments. All that has to be deducted is the moisture which has evaporated, and the water which is lost in the clefts and holes of the mountain.

Thus several of the rivers which spring from glaciers afford a very considerable flow of water. The discharge of the Aar, as it springs from the ice, fluctuates between 5 and 30 cubic yards of water a second. The Rhone, the Rhine, and the Arveiron also form considerable streams as they issue from their changeable grottoes. In summer, when torrents of water rush forth from the glacier, they bear with them masses of *débris* and excessively fine sand and mud, proceeding from the

GLACIERS OF GEISBERG & OF ROTHMOOS

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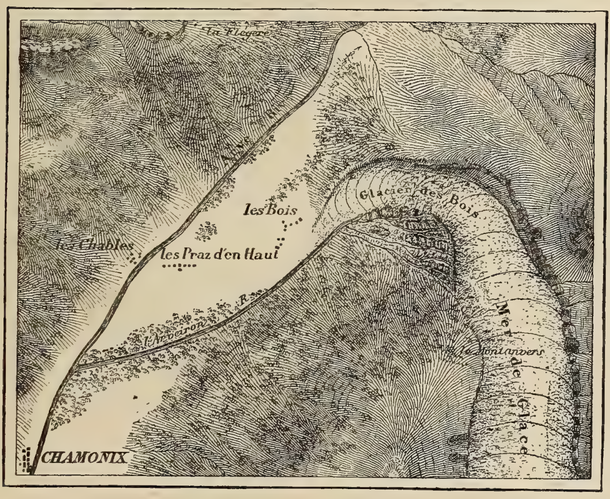
continual grinding of the rocks by the under surface of the glacier. The water holding this matter in suspension is yellow, grey, or blackish, according to the nature of the rocks over which it flows in its sub-glacial course. During the cold season, when it is all frozen along its rocky bed, the stream usually becomes perfectly limpid; nevertheless, a certain number of mountain streams are mentioned, the colour of which always resembles that of the ice itself; the quantity of small *débris* with which they are charged gives them a shade both turbid and bluish, as if they were mixed with milk.

An arcade of vast proportions generally rises over the source. Some of these open out with gigantic and almost regular portals with pointed arches, hollowed out of the ruin-like cliff which terminates the glacier. But each advance and each retreat of the mass of ice results in an alteration of the shape and appearance of the grotto out of which the stream flows. Sometimes the vault above partially

Fig. 84.—Sources of the Arveiron.



gives way under the weight of the upper strata, and large sloping layers become detached from the sides or from the arch; fissures and *crevasses*, like the clefts in cavernous rocks, cut through the walls of ice in every direction, and every now and then blocks break away and fall with a crash into the torrent. Visitors, therefore, who wish to admire closely the vault of crystal, and to contemplate the lovely effects of light which are produced by the reflections of sunshine passing through the transparent ridges at the edges, and falling on the blue-tinted walls, are not able at all times to venture without imprudence into the depths of the cavern. Blocks of ice and rocks often obstruct the flow of the water, and it is but very rarely that these deeply-caverned watercourses preserve much regularity of form for any considerable time. Nevertheless, several instances are mentioned of men who, having fallen into the bed of the stream through a *crevasse* in the upper part of the glacier, have been able to find their way again into the open air, by following the

course of the water across the scattered *débris* and through the frightful darkness of these unknown gulfs. In the very depth of winter, the entrance to the terminal arches is sometimes entirely obstructed by snow and ice; the cold checks the torrent and freezes it at the mouth of the glacier. This was the case in January, 1854, when the bed of the Landquart, which is generally fed by the two important glaciers of Sardesca and Silvretta, did not receive a single drop of water. In 1839, the Arveiron itself was entirely dried up.

The mind is all the more vividly impressed with the majesty of these great rivers of ice when the vegetation surrounding them is green and luxuriant, and forms a more striking contrast with the white and blue tinted cliffs. Some of the most beautiful glaciers in the Alps descend right down into the midst of forests of firs, beeches, and larches; and it is through the green foliage of the trees that we catch a glimpse of the white waves of the icy sea and the dark walls of the *moraines*. In other places, fields of corn, or even vineyards and gardens, extend to the very base of the solid river, and sometimes, it is said, they have to mount upon fallen blocks of ice in order to gather the fruit off the branches of the cherry-trees. Thus the cultivation of the temperate zone, and the ice-fields of the pole, which, on the Continent itself, are separated from each other by thousands of miles, are here brought into close juxtaposition; man's labour and nature in her inviolable grandeur come in contact here without the least transition. This sudden passage into a virgin region, devoid of all activity, conveys an effect of grandeur which deeply impresses the imagination. It is difficult to restrain a feeling of awe at the sight of these enormous rivers of ice slowly marching on, from century to century, with their white or bluish layers, 300 feet high, descending gradually, *en masse*, a few inches a day, carrying with them the fragments of mountains, and grooving out in their course deep furrows in the bed of rock through which they flow. These glaciers seem as motionless as the peaks which tower over them, and yet they roll on as surely as the stream to which they give rise. The solid waves which roughen their surface rise and fall, in the long run, just as those of the sea. They, too, have their eddies and their whirlpools; and the mighty *moraines* which they throw from them at the outlets of their gorges are as much an alluvium as the mud or sand of a river, or the deposits forming along the sea-shore.

CHAPTER XXXIV.

PROGRESS AND RETIREMENT OF GLACIERS.—APPEARANCE OF THE BED WHEN ABANDONED BY THE ICE.—ROCHES MOUTONNÉES.—PARALLEL FURROWS.

IN several parts of the Alps the mountaineers, influenced by the superstitious ideas of former days, continue to believe that the base of a glacier advances and recedes alternately every seven years. The fact is, that if the progress and retreat of the fields of ice take place under the influence of any regular law, this law, which, at any rate, must be disturbed by many special local phenomena, has not yet been discovered. Since the date when regular observations first began to be made on the forward motion of the Alpine glaciers, they have been subject to very considerable fluctuations in their movements. Sometimes they have advanced, sometimes they have receded, and sometimes even they have remained stationary for several years together; but it appears that, on the whole, they have moved onwards. Several of the Swiss glaciers—those of Zmutt, Aletsch, the Rhone, the Aar, and Grindenwald—have increased in length in their rocky beds.

It appears to be certain that, in spite of temporary retirements, some fields of ice, even in the last century or two, have extended sufficiently to close mountain passes which were once practicable even for horses. Thus, several passes in the groups of Mont Blanc, Monte Rosa, and the Bernese Oberland, which still remained open in the fifteenth century, and were indeed used for troops, became more and more difficult to cross, and ultimately, during the course of the eighteenth century, have been rendered inaccessible, either for horsemen or pedestrians. The Lötschenpass, near the Gemmi, which was used less than a century back, is now closed up. Several facts of this kind have been noticed in the Tyrol. One of the Œtzthal glaciers, that of Gurgl, has certainly advanced a mile and a quarter since the year 1717, for that was the date when it commenced to dam up the side valley of Langenthal, in which the stream has accumulated to form a lake. In like manner, in Asia, the glaciers of the Karakorum seem to have uniformly advanced during the course of a century at least. The pass of Jusserpo was formerly accessible to horsemen; it can now only be crossed on foot. The glacier of Boltoro and the ancient pass of the Mustag have become impracticable. But this is not all; several Alpine glaciers are named as being of recent formation. Among these are the Dreckgletscherli ("little glacier of mud") of the Fauldhorn, which was not in existence at the commencement of the century; the Rothelch, a field of ice on the Simplon, dates from 1731; another, descending from the Galenhorn, in the valley of Saas, was formed in 1811; lastly, the fine Glacier de Rosenlaui itself is of modern origin.

Are the glacial encroachments which have taken place on various mountain chains to be attributed to some cause acting generally over the whole planetary surface? This is the theory advanced by Adhémar and still maintained by his disciples. According to their view, the gradual cooling of the northern hemisphere during the present period is completely proved by the increase of the glaciers of Greenland, the Alps, and the Himalaya; but the observations made up to the present time are neither numerous nor decisive enough to authorise any such conclusion. And even if there was a uniforn advance into the valleys on the part of glaciers everywhere, their progress might also be attributed to an increase of the humidity contained in the air, or to some change in the general direction of winds. Numerous instances may be mentioned of glaciers existing on the flanks of the same mountain, advancing with more or less rapidity according to the quantity of snow that falls directly, or is displaced after its fall by the atmospheric currents. Sometimes even a glacier has been noticed to increase in length, whilst near it, or on the opposite side of the mountain, another field of ice has diminished in size. Phenomena of this kind are evidently owing to the unequal distribution of snow on the various slopes. Very considerable falls of *débris* on the surface of a glacier will also result in the prolongation of the icy current into the valley, because the layer of rubbish causes the annual ablation to decrease to a very important extent. Perhaps even, as Otto Volgar points out, the gradual upheaval of certain mountain groups is also one of the causes which contribute to the extension of rivers of ice.

Nevertheless, if during modern times a certain number of glaciers have unquestionably advanced, others have certainly receded, and consequently their bulk has become lessened. Thus, in the Pelvoux group the two important glaciers of Bonnepierre and Chardon have continued to decrease in length and thickness since the year 1850, and this movement of contraction was still continuing in 1861. In like manner, in the Tyrolese Alps, all the glaciers of the Adamello group are diminishing regularly. The Mandron, the most important of all, has been retiring at least since 1825, and in the year 1864 especially had lost about 66 feet of its length. In the same year, the glacier of Fargorida lost nearly 100 feet, and the inhabitants of the country say that since the beginning of the last century it has continued to diminish in importance. It appears also that in certain places the fields of ice reposing on the summits have also disappeared.

During the forty years which have elapsed from 1826 to 1866, the glaciers of Mont Blanc have also lost much both of their length and of their force, evidently because the snow in winter has been less abundant, and the summers on the average have been hotter. The Glacier du Tour, which once invaded the valley of Chamounix, has retreated, on the whole, 567 yards since 1854, and does not reach beyond one of the upper passages, invisible from the road. A stone which marks the precise spot reached by the Glacier des Bois, or Mer-de-Glace, in 1826, stood in 1865 at 424 yards from the arch of the Arveiron, and at certain spots, according to the evidence of M. Bardin, the ice had decreased more than 100 yards. The Glaciers des Bossons and Argentière, the two other great glaciers of the valley, each of which used to threaten the village that was nearest to their frontal *moraine*, have receded 362 yards and 197 yards respectively during the period from 1854 to 1866. Although they have diminished in length more slowly than the Glacier du Tour, it is evidently because the basin which they occupy is much more considerable, and the *névés* above have never ceased to feed them. We must also add that, during these twelve years, the superficial ablation has in every case perfectly corre-

1 : 59.000.

33.9 = 2 Kilomètres.

sponded with the retirement of the ice. The Glacier des Bossons has lost about 88 yards in thickness. Previously to 1854, the lateral *moraines* lay much lower than the mass of the glacier; they now tower over it at a mean height of 82 feet.

The true system of action of glaciers seems to be pointed out by the alternations of progress and retreat, established both by official documents and scientific observations with regard to the lower part of the Glacier de Vernagt, in the Œtzthal group. The fluctuations of this river of ice have been noticed for nearly three centuries, and the chronicler who mentions them for the first time in 1599, adds that these motions to and fro are the "natural habit" of the glacier. The Vernagt descends rapidly towards the valley, and striking against a wall of rock which rises up directly opposite to it, obstructs the passage of the Rosenthal waters, which there form a lake. Then the enormous obstacle gradually sinks, the glacier slowly recedes towards the steep slopes, until some fresh impulse of the *névé* again forces it on towards the bottom of the valley. Without reckoning the less important fluctuations, we find that the intervals between each great enlargement have been seventy-eight, ninety-three, and seventy-three years, which gives an average of eighty-four years. Like rivers of running water, the Glacier de Vernagt has its floods and low-water seasons. From 1843 to 1847, at the time of the last irruption of the ice, it advanced 1,455 yards, and spread out in the valley over a width of 1,382 yards. At the lower part the ice was not less than 518 feet above the stream, and, higher up, the glacier, at certain spots, attained a thickness even twice as great. The swiftness of progression of the front of the glacier was quite unexampled. During the two first years it exceeded $6\frac{1}{2}$ feet a day; at the end of the month of May, 1845, it attained a rate of progress of 42 feet in the twenty-four hours. On the 1st of June the speed measured was not less than 6 feet 3 inches an hour, equal to about 150 feet in one day. The motion of the ice could be detected even with the naked eye. The thunder of the opening *crevasses* and of the *séracs* falling down was incessant. Finally, however, this terrible invasion, which threatened all the valleys below, was arrested, and the stream of ice receded, giving a passage to the lacustrine waters which it had penned up. Since this epoch the lower portion of the Glacier de Vernagt has continued to decrease, but still here and there, on its former bed, it has left islands of ice protected against the heat of the sun by masses of *débris*. After resisting the elements for years, these isolated heaps sink and finally disappear. In the state of Kashmir the Tarshing glacier, which of all Indian glaciers descends the farthest towards the plains, at an altitude of 9,500 feet, on the slopes of the Nanga Parbat, presents phenomena of advance and retreat analogous to those of Vernagt, but on a far larger scale.

By means of the temporary or permanent retirement of certain glaciers we are enabled to ascertain the effect produced by the gradual flow of these enormous masses on the bottom and sides of their rocky beds. The numerous observations of M. Dollfuss-Ausset seem to have established the fact that above 8,530 feet, that is above the ideal line of perpetual snow, the Alpine glaciers only rub away the stone in a quite imperceptible degree, on account of the freezing which causes them to adhere to the surface of their bed. But, below this altitude, the incessant friction of the ice and the gravel it carries with it gradually removes the most prominent roughness, and ultimately gives a rounded surface to all the projections. To use a comparison which is frequently applied, a glacier passes over the ground like a gigantic plane; it works over the bottom of its bed, and overriding all the

projecting points, grinds them down, pulverizes them, and reduces them to the condition of sand. It subsequently makes use of this very *débris* for rubbing away and polishing the rocks in its bed; hence, therefore, arises that mammillated aspect of the old projections over which the heavy mass has glided for so many centuries. Clefts and fractures appear like dark lines of shade on these round, white, polished lumps, which sometimes have the appearance of heaps of wool placed upon the ground, or of flocks of sheep. They are thus known under the name of *roches moutonnées,* a name employed for the first time by De Saussure.

In making its way towards the plain, the glacier does not confine itself to rubbing off the more prominent parts of the rock; it also scoops out the stone in certain places by means of the variously shaped blocks of greater or less hardness with which it is armed on its lower face, which act as so many chisels on the rocks beneath them. The stones which are slowly impelled towards the bottom of the glacier are scratched as by stylets of stone, and the rocky bottom of the gorge itself is furrowed up and down as by a ploughshare. The walls of the bed of ice are likewise grooved by the rough edges of the blocks carried along on each side of the current. Nevertheless, wherever the bed of the glacier is narrowly confined between two promontories, it is only the up-stream faces of the latter which present streaks, furrows, or other traces of rubbing, and the down-stream faces retain all their natural clefts and original projections. Sometimes, in portions of the bed abandoned by the ice, we may meet with circular cups or basins, like the holes which the sea or rivers hollow out on their shores. These glacier-cups originate in a similar way to those in river-banks and cliffs: they are formed by stones incessantly turning round and round under the influence of sub-glacial torrents, or the cascades pouring down into the gulfs of the *moulins.*

CHAPTER XXXV.

DISTRIBUTION OF GLACIERS OVER THE SURFACE OF THE EARTH.

MOUNTAIN summits which rise above the limit of perpetual snow do not all give rise to rivers of ice; the concurrence of several meteorological and orographical conditions is necessary in order that the snow and *névé* should be changed into glaciers. In the first place, it is requisite that the snow zone of the mountain tops should be of some considerable breadth, and that vast beds of *névé*—those reservoirs for the supply of glaciers—should be formed in the mountain amphitheatres and in the upper plateaux. It also requires that the winds which blow against the mountains should be charged with an amount of humidity sufficient to leave immense beds of snow on the summits and the slopes. Added to all this, the gorges which open into the thickness of the chain must be of a gentle inclination, so that the snow may not slide down immediately into the valleys below in the form of avalanches, and the mountains themselves must be grouped in such a way that their gorges unite to form a common basin, where the snow may be finally elaborated in order to constitute genuine rivers of ice. Lastly, it is indispensable that the various seasons of the year should afford extremes of temperature sufficiently great to allow of the phenomena of thawing and regelation taking place in the masses of *névé*. It is owing to the great uniformity of climate that so little ice is seen on the sides of the lofty snow-clad peaks of the equatorial Andes.

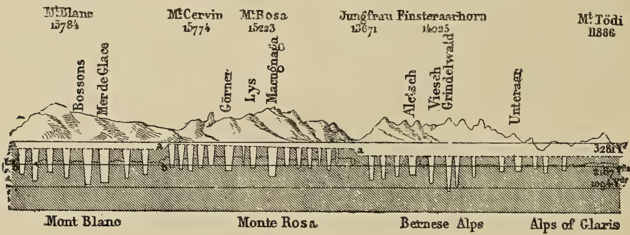
The large number of different conditions which must all be combined as necessary to the formation of glaciers, will readily show why these rivers of transformed snows are comparatively very rare in the regions of torrid and temperate zones. They are produced with a high degree of uniformity and grandeur only on the sides of lofty summits; whilst on mountains of less elevation, as those of the Vosges and the Riesengebirge, they are formed in very snowy years in the recesses of ravines sheltered from the sun. It is, however, only in the vicinity of the poles that the ice-system manifests all its magnificence, and, indeed, constitutes the predominant feature of nature.

In Europe, the central Alps form the orographical system in which all the conditions necessary for the formation of glaciers are fulfilled at the greatest number of points. These mountains, too, will ever remain for *savants* the classical region of glaciers, for among them a De Saussure, a Charpentier, an Agassiz, a Rendu, a Forbes, and a Tyndall have gone on from discovery to discovery, and have ultimately brought to light the true theory of the motion of ice. There are in the Alps nearly 1,100 glaciers, a hundred of which may be looked upon as

primary glaciers. The total surface of the fields of snow, *névé*, and ice on the Alps is estimated by the brothers Schlagintweit at 1,177 square miles, or about one-seventh of the whole area of the great mountains from the Pelvoux to the Gross-Glockner. The glaciers of Mont Blanc alone, though inferior in extent to those of Monte Rosa, cover a surface of 109 square miles. According to M. Huber, their total mass amounts to nearly 1,834 millions of cubic yards, and represents a body of water equal to the whole of the discharge of the Seine during nine years.

The glaciers of the Alps descend on the average to a point about 7,414 feet above the level of the sea, that is, about 1,650 to 2,000 feet below the level of perpetual snow; but there are a great number of glaciers, and they are generally the most important, the base of which is below the mean altitude of about 7,000 feet. The Mer-de-Glace, the receptacle of the greatest part of the snow of Mont Blanc, reached in 1862, at the source of the Arveiron, a point which is only 3,659 feet above the level of the sea. The Glacier des Bossons, fed by the snow of the same mountain group, descended to a level of 3,605 feet; lastly, the lower glacier of Grindenwald, which of all the glaciers in the Alps pushes its way the farthest into the valleys below, has its terminal grotto placed at only 3,225 feet above the sea-level. This fact must be attributed to the northern aspect of the glacier, to the

Fig. 85.—Glaciers of the Alps; after A. and H. Schlagintweit.



a a, Lower limit of persistent snows. b b, Lower limit of secondary glaciers.

narrow straits of rocks through which it has to flow, and its rapid declivity, exceeding 14 degrees. With regard to the Glacier d'Aletsch, which in its dimensions is the most important of all, and rolls down a wide current over a total length of 23,304 yards, it does not descend into the lower gorges, and in 1860 it stopped at an altitude of 5,137 feet above the level of the sea. The Glacier d'Aletsch owes its enormous development to the great body of *névé* collected in the high mountain hollows. This glacier has a total area of no less than 130,000,000 square yards.

The glaciers of the Tyrol are numerous, since, in the Œtzthal and Stubaier groups alone, Sonklar reckons 309 glaciers, 16 of which are of the first class. It is true that, in his enumeration, the learned explorer of the Œtzthal has not omitted a single one of the small glaciers lying on the sides of the mountains. Some of the rivers of ice, especially the Vernagt, the Gepaatch, the Murzoll, and the Gurgl, are important streams, and well known to *savants* through the investigations of the brothers Schlagintweit, Simony, Sonklar, and other geologists; they are, however, inferior in extent to the principal Swiss glaciers. The minor importance of the Tyrolese ice-rivers compared with those of the Western Alps is principally to be attributed to the unequal distribution of snow in the two countries during the

GLACIERS OF LANGTHAL AND GURGL

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various seasons of the year. Not only does it rain and snow in larger quantities on the Swiss mountains than on those of the Œtzthal, but in the latter groups the snow falls principally in summer, and consequently melts before it has a chance of increasing the mass of the glacier. The winter snows, which alone contribute to feed the ice-rivers, are more than twice as abundant on the lofty summits of

Fig. 86.—The Glacier d'Aletsch.

Switzerland as on those of the Tyrol. The annual layer of *névé* which is formed on the Bernese Alps attains, according to Agassiz, a thickness of 2 to $2\frac{1}{4}$ yards, whilst on those of the Œtzthal it scarcely reaches a yard. Nevertheless the latter group affords an area of 221 square miles of ice, equal to one-seventh of its whole surface.

The two other principal groups of the Eastern Alps are those of the Ortelspitze, south of the Œtzthal, and the Gross-Glockner, very much more to the east. In the latter is situated the fine glacier of Pasterze, the dimensions of which, including the *névé*, are, according to the brothers Schlagintweit, 10,274 yards in length, 4,494 yards in width, and 236 yards in depth. The rest of the Austrian Alps possess only two isolated glaciers, that of Dachstein, not far from Hallstadt, and that of Marmolata, above the plains of Venetia. In order again to meet with such mighty ice-rivers, we must turn to the other extremity of the Alpine system, to the south and south-west of the great central groups of Monte Rosa and Mont Blanc. There each of the great groups of Piedmont and Dauphiny, the Grand-Paradis, the Vanoise and Grande-Casse groups, the Grandes-Rousses, and especially the Oisans, afford glaciers of the highest importance.

The mountains of Oisans, Pelvoux, the Ecrins, and Aiguille-de-Meije are almost as distinguished as Mont Blanc itself for the quantity of ice they bear on their slopes. There is no region in the Alps in which the phenomena of these vast ice-rivers can be better studied than in the upper valley of the Banc, situated at the point of junction between the Glacier-Noir and the Glacier-Blanc, at the foot of the pyramid of Pelvoux. Just at the spot where the lower extremities of these mighty masses, now confined between two vertical walls of ice, unite their lateral *moraines*, they present a most perfect and striking contrast. As viewed from the plain of *débris* lying between the two *moraines*, which is traversed by the stream of the Banc, the Glacier-Noir is so loaded with *detritus* of every kind that it looks like an immense flow of mud, such as those vomited out by the volcanoes of Java. The real nature of this mass could not be recognised, were it not for the gaping *crevasses* into which blocks of stone and trains of pebbles ceaselessly fall with a dull noise. At the foot of the glacier leans the frontal *moraine*, more than 300 feet high, with muddy rivulets trickling through its rocks and creeping away slowly among the scattered *débris* of the plain. On the other side the Glacier-Blanc, almost entirely free from rubbish, is terminated by gigantic steps, themselves supported by vertical buttresses somewhat resembling a lion's paw. The beds are of a pure white, here and there streaked with red and gold-colour. From the middle arch, which is admirably curved aud supported by blue pilasters, flows the tributary of the Banc, with water of a milky white. To the east, on the other side of the valley, stands the Pelvoux, resembling a Gothic spire enriched with turrets; between each of its peaks there are small fields of ice, which look in the distance like slabs of white marble.

To the south of the important Oisans group, the glaciers only appear singly in the upper gorges of the loftiest mountains. In no place do these small isolated streams combine to form an ice-river which, like those of the great Central Alps, pushes its way down into the valleys at the base of the mountains. The Viso, and some peaks of the Maritime Alps, present small ice-fields; the last in this part of the chain is that of Clapier-de-Pagarin, between Nice and Valdieri.

If we comprehend in one glance the whole map of Central Europe, we shall see that the principal glacier groups are those which surround the mountain summits of Mont Blanc, Monte Rosa, the Finsteraarhorn, Bernina, and Œtzthal. The following table, from which we clearly see that Monte Rosa is the true centre of the region of ice, shows the comparative importance of each system of glaciers. According to Studer, it is owing to the heightening of the temperature produced by the lofty plateaux of Engadine, that the fine group of the Bernina is distinguished from all the rest by the comparatively small quantity of ice which it possesses.

ANCIENT GLACIERS OF THE VALLEY OF THE ADIGE

Profile of the old Glaciers of the Valley of Adige

$\frac{1}{1.365.000}$

Kilomètres

5 10 20 30 40

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Mont Blanc.	Yards.	Monte Rosa.	Yards.	Finsteraarhorn.	Yards.	Bernina.	Yards.	Œtzthal.	Yards.
Mer-de-Glace	15,966	Græner	16,732	Aletsch	26,246	Mortirat	10,170	Gepaatch	12,357
Argentière	10,607	Ferpècle	15,529	Viesch	16,185	Forno	9,623	Gurgl	10,936
Bionnassay	10,498	Zinal	11,701	Unteraar	15,638			Hintereis	10,061
		Findelen	11,154	Tschingel	9,514			Murzoll	9,623
		Zmutt	9,404	Lötschen	8,530			Mittelberg	8,530
		Turtmann	8,311	Oberaar	8,420			Vernagt	8,311
		Ried	8,311						

The Pyrenees, which lie more to the south, are neither so high nor so well-arranged in groups as the Alps; they consequently afford a much less extent of snow-fields and glaciers. The area occupied by the latter has not at present been brought into comparison with the superficies of the whole chain, but it certainly does not reach a hundredth, and perhaps not even a thousandth, part of the total surface. The Pyrenean glaciers, which are about a hundred in number, are almost entirely *serneilhes,* or summit-glaciers, and do not descend into the lower valleys. There is, perhaps, only one—the eastern glacier of the Vignemale—which assumes the shape of an ice-river, and the spot in the gorge where it stops is as much as 7,208 feet above the level of the sea. Nevertheless, although the Pyrenees cannot be compared to the Alps either for the magnitude or the development of their glaciers, those that are found in the former chain are in no way less remarkable for their deep *crevasses,* their blue-tinted walls, their little lakes covered with thin ice, and all those other varied phenomena which confer such a charm on the study of the Swiss glaciers.

The Carpathians are entirely devoid of glaciers. The mountains of the Caucasus which, in the general configuration of Europe, may be considered as the chain corresponding to that of the Pyrenees, are much richer in ice-fields. One, the Desdaroki, descends as low as 6,495 feet above the sea, which gives a vertical height of something less than 12,000 feet to the whole of the Caucasian snow and ice-fields, between the lowest *moraine* and the summit of Elburz, rising to an elevation of 18,405 feet. Nevertheless, the glaciers of the Caucasus are not equal to those of the Central Alps, either in magnitude or beauty, which is, no doubt, caused by the comparatively small quantity of rain and snow which falls in this part of the Old Continent, and also by the large amount of summer heat which prevails there.

The most important glaciers of the northern temperate zone are probably the enormous ice-rivers of the Himalayas and the Karakorum. In comparison with the immense flows of snow which descend from the principal summits of Asia, the largest glaciers of the Alps must be considered as belonging only to a secondary order. The largest glacier in the Indian mountains—that of Biafo, in the valley of Chiggar (Karakorum)—is not less than 36 miles in length, more than 21 miles longer than that of Aletsch in Switzerland. The area that it occupies is several hundred square miles in extent, and in its vicinity there are other ice-fields, such as the Baltoro and Mustag, which are but little inferior in magnitude. The quantity of ice which almost entirely fills up each of these important valleys of the Karakorum cannot be estimated at less than ten times that which lies in the Mer-de-Glace and the Mer d'Aletsch. It is a very remarkable fact, in regard both to these glaciers and those of the Himalaya, that the ice-rivers are much longer and more abundant on the southern side of the mountain than on the colder slopes which are turned towards the north. This phenomenon must evidently be

attributed to the larger quantity of snow brought by the south wind, and impeded in its course by the lofty summits.

The northern mountain chains of the Old World are of considerable less elevation than either the Alps or the Himalayas, and do not present any glaciers so remarkable for their extent as those of the great central groups of Europe and Asia. Nevertheless, the proximity to the pole compensates in part for the inferior altitude of the peaks. Thus, the high plateaux which terminate the Scandinavian mountains, exposed as they are to the winds from the west, so fully charged with aqueous vapour, present vast fields of snow, and the greater part of the ravines which sink down towards the *fiords* on the coast are filled up with glaciers descending as low as 1,640 feet, or, as in the case of the Boudhusbraen, even to 967 feet above the sea. Among the numerous ice-rivers, the most important is that of Lodal, which flows from the immense *névé* fields of the Justedal; it is nearly five miles long, and 880 yards broad, and descends to a point only 1,320 feet above the level of the sea. The total area of this glacier is very inferior to that of some of the primary Alpine glaciers; it is estimated approximately as being about one-seventh of that of the great ice-stream of Aletsch.

Although the Ural Mountains, like the Scandinavian, are situated under a very high northern latitude, they do not possess a single glacier, and do not even reach the limit of perpetual snow. On their summits, the height of which varies from 4,000 to 5,000 feet, there are no continuous snow-fields to be noticed in the middle of summer, no snow, in fact, but isolated drifts in the cavities of the rocks. The surprising contrast between these mountains and those of Scandinavia may be explained by the inferior quantity of rainfall which is discharged in the former region, and doubtless also by the comparative narrowness of the chain and its isolation in the midst of the *tundras*, which, although traversed by cold winds in winter, in summer reflect the rays of a burning sun. Nevertheless the other mountain chains—much loftier, it is true—which surround the south of Siberia, have their fields of perpetual snow and their rivers of ice. In the Altaï, the glacier of Katunia descends to a point which is 4,068 feet above the level of the sea.

The countries of the Arctic zone—Spitzbergen, Jan-Mayen, and Greenland—are the domain *par excellence* of *névé* and glaciers. In those regions the mountains are uniformly covered with snow above an altitude varying from 900 feet to 1,500 feet, and the fields of ice which flow down into the valleys reach very nearly to the sea-shore. The few travellers who have climbed a summit from the height of which a vast extent of country can be surveyed, have seen in that part of the horizon which is occupied by land little else than an immense white sheet, pierced here and there by black pointed rocks.

The glaciers of these polar regions differ in no way from those of the Alps, except that in consequence of the inferior altitude of the snow the *névé* has a very considerable extent as compared with the glacier proper. Sometimes, even, it has been asserted that the lower portions of the ice-rivers of Spitzbergen present both the appearance and the structure of *névé;* this, however, is an error. In these polar countries, the glaciers have also their *crevasses* and their *moulins,* their stratification and their blue belts, their *moraines* and sub-glacial streams. Only, the thickness of the mantle of snow which covers the whole country and the surface of the glacier itself, generally give it a considerable uniformity of aspect; the stones of the *moraines* appear on the surface in but few spots, and as to the mass of *débris* which ought to accumulate in front of each glacier, they must be sought for in the

bed of the sea, into which the blocks are precipitated which break away from the principal mass.

In North Greenland the vast Humboldt glacier is no less than 66 miles broad at its lower end, and the frozen mass descends to a depth of 2,000 feet into the sea. Of equal magnitude is that of Dove on the east coast. Till recently the Eisblink, south of Godhaab, was wrongly supposed to be the largest existing glacier. The lower portion of the enormous mass pushes out into the midst of the sea, forming a cape, the length of which is more than 13 miles, and if a glance is thrown back towards the heights between the two walls which enclose the river of ice, the Eisblink may still be seen on the extreme horizon, that is, 35 to 40 miles away. The incline of this sea of ice is very gradual, and it blends insensibly with the horizontal surface of the icebergs on the shore. As the glacier does not terminate on the ocean coast in steep cliffs, it is impossible to discover the point underneath the ice which forms the boundary between land and water. There is, however, a considerable mass of submarine *débris*—the Tallert Bank—which stretches around in a semicircle in the sea, just off the end of the glacier. This is probably a kind of frontal *moraine* carried down by the stream which incessantly flows under the Eisblink.

The greater part of the streams which descend from the mountains in the interior of Greenland likewise remain hidden, during their whole course, under enormous moving ice-fields, and only betray their presence by bubbling up in different places, and by the muddy colour and diminished saltness they communicate to the sea-water with which they are mingled. Some streams which pour down a considerable quantity of water hollow out for themselves wide beds under arches of ice, which press with an enormous weight on the pillars that support them, and which are always tending to break down under the pressure of the masses above. At the same time the waves of the sea, the temperature of which is much higher than that of the glacier, are melting away the base of the columns, and incessantly sapping them by their repeated shocks. This frequently results in the downfall of immense masses of ice, like whole sides of mountains, which give way suddenly with a crash.

The downfall of one of these terminal cliffs of ice in Greenland and other northern countries presents a magnificent spectacle—as in the glacier of Horn Sound, on the south of Spitzbergen, a prodigious mass, 150, 300, or even 400 feet high, rests entirely on the sea, which has gradually melted away the under portion of the ice with which the waves have come in contact. At low tide the enormous overhanging mass, under which it is quite possible to penetrate in a boat, hangs without support, and is only kept up by its cohesion with the rest of the ice and with the sides of the adjacent rocks. Still the mass continues to advance, and the numerous partial ruptures which take place in its bulk cause a noise similar to the crackling of the electric spark. All of a sudden the great crash takes place; enormous sections of ice break away from the cliff with a roar like thunder, and sink down into the depths of the water; they soon, however, re-appear on the surface of the waves, oscillating to and fro to find their equilibrium, and, impelled by the winds and currents, float away on the undulating billows.

In the continent of the New World, the glaciers on the mountains farthest to the north resemble those of Greenland and Spitzbergen in likewise reaching the sea-coast; but in the south the lower limit of glaciers rises rather rapidly. In a gorge at Mount Forbes, situated near the 52nd degree of latitude, there is one which descends to the point of 4,281 feet above the sea. Mount Renier, between

the 46th and 47th degree, has on its sides small glaciers over which the burning lava sometimes flows. But farther to the south there are no other summits, either of the Rocky Mountains or the Sierra Nevada (not even those that rise more than 13,000 feet in height), which have on them fields of ice; all that is to be seen are the *moraines* and the furrows, telling the story of former glaciers now disappeared. Neither are the *névés* of the Rocky Mountains very extensive—a fact which may be explained by the dryness of the air and by the rapid evaporation which results from it.

In the tropical zone, the only mountains of America which exhibit small glaciers are the lofty summits which exceed 16,000 feet in height. Of this kind are Orizaba; some peaks of the Sierra Nevada; of Santa Marta, and of the Sierra of Cocui, in New Granada; the Altar of Ecuador (the former crater of which is filled up with ice), and Illimani, in Bolivia. Nevertheless, these small glaciers, as compared with the extent of the *névé* and the dimensions of the mountain-chains themselves, have no geographical importance. I may therefore be allowed to repeat, in common with most other authors, that the Andes are devoid of ice over an extent of more than 3,000 miles, from the confines of Venezuela to the centre of Chili. The Descabezado de Maule, on the 35th degree of south latitude, is the first Chilian mountain on which we find an ice-field. But, south of the peak, glaciers become more and more numerous, and, according to Philippi, present in their structure and movement the same varied phenomena as the beautiful glaciers of the Alps. On the Patagonian coast, south of Chiloe, the terminal faces of the glaciers appear in all the valleys in close proximity to the sea-shore. Even in the latitude of 46° 50′, a position corresponding to that of the hills of Poitou in the northern hemisphere, the ice-rivers make their way to the sea, and the fragments which are detached from them go floating away to the north. The fact is, that the fall of rain and snow is very considerable on the western slopes of these mountains; added to this, it is a matter of certainty that the mean temperature is lower in the southern hemisphere than in the northern.

Omitting any mention of the glaciers in the Antarctic regions, which have never been closely examined, the phenomena of which must exactly resemble those of the glaciers of the northern zone, there are still some very remarkable ice-rivers in the southern hemisphere which call for our notice. These glaciers flow down the sides of the Alps of New Zealand—the great southern island. The glaciers on the eastern side of the chain do not descend so low as those on the western slopes, because the quantity of rain and snow poured down on the former is much less considerable. The great glacier of Tasman, which flows towards the east, terminates at a point 2,739 feet above the sea; whilst the glacier of Waiau, which fills a gorge tending towards the west, descends as low as 700 feet above the sea-level, and hurls its *débris* amongst the green ferns, pines, beeches, fuchsias, and other plants of the lowlands. The position of this glacier (43° 35′) corresponds with the latitude of Cannes and Antibes in the northern hemisphere. Now, in the Swiss Alps, the glacier which descends the lowest scarcely attains the point of 3,300 feet above the sea. We must go twenty degrees farther north, to the coasts of Norway, to find the most southern glacier which has its terminal face so little above the sea as that of the glacier of Waiau.

CHAPTER XXXVI.

THE GLACIAL PERIOD.—ANCIENT GLACIERS OF EUROPE.—DISPERSION OF ROCKS AND BOULDERS FROM SCANDINAVIA AND IN NORTH AMERICA.—ANCIENT GLACIERS IN TROPICAL REGIONS.

A STUDY of the existing phenomena which are presented to us in the Alpine glaciers has brought to light the unexpected fact that, at a comparatively recent geological epoch, their dimensions were much more considerable than they now are. Under the influence of meteorological conditions which certainly differed from those of the present period, which conditions, however, are still the subject of somewhat animated discussion, the ice-rivers descended to great distances from the ridge, and reached the extremity of some valleys which, during the present epoch, have become richly cultivated tracts. This fact is evident from the *striæ* running along in parallel lines at great heights on the mountain sides, also from the gigantic *moraines* which in times gone by were pushed forward as far as the outlet of the valleys, and the rocks which were formerly transported by the ice from one chain of mountains and thrown upon the opposite slopes of another chain. Indications of a perfectly similar character to those which mark the extent of the comparatively trifling fluctuations of the glaciers of our day serve also to measure the former developments of the enormous ice-rivers of the past.

One of these indisputable signs is the upper limit of the traces of friction left by the ice in its course towards the valleys. It appears that on the sides of Monte Rosa and the Bernese Alps this limit does not exceed a height of 10,000 feet; but the slope of most of the ice-fields was then much less abrupt than it is at present; it did not exceed two degrees, and at some points on the banks of the former glacier of the Aar it was even less. The considerably larger quantity of the ice in motion at that time allowed the whole mass to make its way over a very slightly inclined bed. The subjoined illustration, borrowed from M. Viollet le Duc's work on Mont Blanc, will give some idea of the magnitude of the Alpine glaciers in former times.

In like manner the glacier of the Rhone, which now occupies a mere gorge in the Valais Mountains, filled in those days the whole space included between the groups of the Finsteraarhorn and Monte Rosa, and, from every lateral valley and every ravine which opens out right and left in the thickness of the chain, it received a fresh addition of ice and *moraines*. The immense ice-river thus extended as far as the shore of the Lake of Geneva; it even went beyond it, and spread over the plains of Switzerland up to the Jura, joining, at its lower extremity, the glaciers of the Isère and the Ain. A field of 1,000 feet of ice stretched over the valley at the

very spot where the Rhone and the Saone unite their waters, and where the city of Lyons has since been built. On the Italian slopes of the Alps, each of the great valleys, where, in the present day, nothing but a few fields of *névé* are to be found in some of the higher ravines, used to serve as a bed for vast streams of ice descending even to the plains of Piedmont and covering the great Alpine lakes. One of these streams, taking its rise in the upper ravines of Mont Genèvre, Chaberton, Mont Thabor, Mont Ambin, Mont Cenis, and Rochemelon, filled the whole of the Susa valley, extending even to Rivoli, at the outlet of the mountains. Another glacier filled the valleys of the Adige, and advanced beyond Lake Garda; these enormous Alpine glaciers were, in fact, twice or three times the size of the largest ice-rivers which are now to be found in the Karakorum and the Himalaya.

The former existence of these glaciers is proved not only by the presence of the *striæ* and marks of friction on the rocks, but also by the frontal and lateral *moraines* which have been pushed forward in former days to the very outlet of the valleys, or which have crumbled down on the slopes. Thus, above the village of Monthey, in the valley of the Rhone, there may still be noticed a mass of stones of very considerable dimensions, forming a kind of rampart more than 3,000 yards in

Fig. 87.—Old Glaciers of the Ferret Valley.

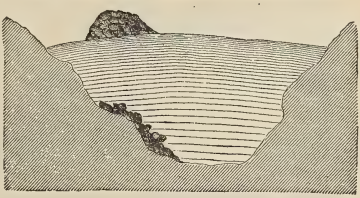
length and 200 yards in average breadth. This bank is formed of granite blocks, brought from the Val de Ferret by a former glacier, and must once have been a medial *moraine* which, after the melting of the ice which carried it along, was stranded on this promontory. At one time, a number of former *moraines* of this kind were found at various spots in Switzerland; but the harder rocks having been much used as stones for building, these remains are disappearing more and more every day.

In many valleys, the stones deposited on argillaceous beds partly serve to protect the soil from weathering, and thus seem to rise in proportion as the surrounding land becomes more deeply eroded. In this way are formed columns, obelisks, pyramids, rising irregularly above the surface, like the remains of some vast and fantastic building. Such formations are locally known as "Colonnes Coiffées."

The question which has given rise to the most animated discussions among geologists is the problem how the *moraines* of the Alpine glaciers, and the great stones which in former times drifted along their course, managed to cross the great lakes of Switzerland and Lombardy. Thus, the town of Lucerne is built upon the *débris* which was once borne along on the immense glacier of the Reuss, which,

descending from the St. Gothard, crossed over the depths of Lake Lucerne. In like manner, to the south of the Lake of Garda, the hills of Solferino, Cavriana, and San Martino, on which was fought the terrible battle of 1859, are nothing more than heaps of stones, which once served as an advanced guard to glaciers. Added to this, erratic masses of stone or boulders proceeding from the Alps—as is shown by the crystalline nature of these rocks—are found on the eastern slopes of the Jura; they are seen at various heights, and even at as much as 3,300 feet above the level of the sea. Among these blocks—a few of which are from 5,000 to 6,000 cubic yards in bulk—there are some which the *savants,* from a study of their mineralogical composition, can clearly specify as having come down from certain mountains in the groups of the Finsteraarhorn, Monte Rosa, and Mont Blanc. By what means have these blocks of rock been able to accomplish their journey before they became stranded on the mountain sides of the Jura? Was the Lake of Geneva much more elevated at a former epoch than it is at present, and did the enormous masses of ice which fell into it from the glacier of the Rhone, and ultimately floated to the opposite bank, enclose blocks of rocks and stones like the icebergs of the northern seas? Or was it the fact that the glaciers filled with their masses the deep cavities of all the lakes of Switzerland and Lombardy, and, like the Rhone, which continues its course after having so widely expanded in order to form the Lake of Geneva, crossed over these lakes and flowed out far and wide into the plains of France and Italy? This last hypothesis appears probable, for on the sides of the mountains which overhang these lakes, and especially round the lakes Maggiore, Como, and Garda, the ancient *striæ* of the glaciers are still to be perceived, and some of the insular rocks retain that *moutonnéed* appearance which bears witness to the fact that the ice had passed over them. Added to this, the protection afforded by the masses of ice which filled them up have probably been the cause why the deep cavities of the lakes were not choked up by the *débris* which fell from the broken ridges above on to the moving bed of the glacier. Some geologists have put forward the hypothesis that the beds of the Alpine lakes were hollowed out entirely by the Alpine glaciers. This view, so ably advocated by Professor Ramsay, the director of the geological survey of England and Wales, has lately received great support from Professor Newberry's investigation of the lake-system of North America.

Fig. 88.—Ancient Moraine falling down.

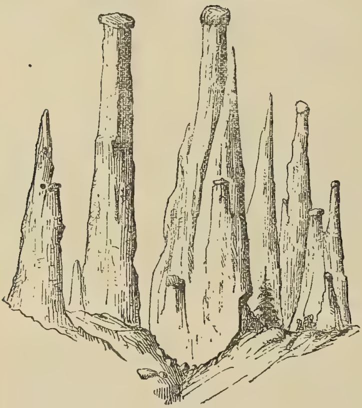


However this may be, the enormous extent of the old ice-rivers of Switzerland is a fact now established beyond doubt. Nor can it be doubted that the same phenomenon was presented in the rest of Europe. From one extremity of the chain to the other, the Pyrenees afford unequivocal evidences of the glacial epoch, and in some valleys, those for instance of Oo and Argelez, the frontal *moraines* are still almost as distinctly visible as if the ancient glacier had melted only the day before. In like manner, to the west of Vosges, the natural banks of sand, gravel, and heaped-up rocks which pen in the water of the little lakes of Gérardmer, Longemer, and Frondomé, are nothing else but old *moraines.* Similar phenomena are found in the mountains of other countries—Wales, Scotland, and Ireland, in the Carpathians and the Riesengebirge.

Another proof of the enormous development of the ice-system during a

comparatively recent epoch may be derived from the dispersion of the erratic rocks or boulders, which are found in such great numbers in the countries of the north of Europe. It is now beyond all question that the numerous lines of rocks which are found here and there all over Northern Russia have proceeded from the granite mountains of Scandinavia. When an immense sea extended over Finland, between the Baltic and the Polar Ocean, the blocks of ice which fell into the water that washed the base of the Scandinavian mountains drifted away in flotillas towards the south-east to the shores of the continent opposite. The prominent angles of the granite blocks contained in the masses of floating ice have traced out long furrows over all the points and projections of the rocks in Finland, which was then only a marine shoal. M. Nordenskiöld has ascertained that almost all these lines of erosion tend from the north-west to the south-east, and that all the rocks with which the icebergs have come into contact are polished on the side which faces towards Scandinavia, whilst on the other side they have in every case retained their uneven surfaces, their projections, and their clefts. With regard to the boulders themselves, they are all the more rounded by friction the more distant they are from the Swedish mountains of which they once formed a part. All the phenomena which once were effected on so vast a scale round the shores of the Baltic are, however, still taking place. During the winter of 1862-3, immense masses of ice, coming from Finland, were cast upon the southern coast of the gulf and thrown up on the land to a distance of more than 300 yards from the shore, and to a height of 30 feet above the level of the sea. The ice, which was 40 to 50 feet deep, overwhelmed many dwellings and whole forests; in the latter large quantities of stones were subsequently found, which the ice left behind when it thawed.

Fig. 89.—Weathered Columns.



These boulders are scattered in considerable numbers over the *tundras* and plains of Northern Russia; they are also found in Prussia and Poland as far as the slopes of the Carpathian Mountains. They are seen round the North Sea, on the coasts of Friesland, England, and Scotland. The investigations also of M. Bohtlingk have shown that erratic rocks, or boulders, have made their way, borne on masses of ice, from the *fiords* of Lapland towards the Northern ocean. Thus the great island of the Norwegian Mountains was once a centre of dispersion from which the rocks, instead of merely rolling to the bottom of the slopes, were distributed in various directions over the immense space included between the British Isles, Spitzbergen, the Ural Mountains, Valdaï, and the Carpathians. Strange to tell, numbers of these Scandinavian rocks, thus stranded beyond the sea, are still overgrown with lichens and other plants belonging to Norwegian families; they might be compared to colonies of poor shipwrecked creatures cast upon a foreign shore.

In the gentle undulating plains of North America, boulders and other *débris*

brought by floating ice are likewise found scattered over wide tracts of country. The vegetable soil of some of the most fertile districts, such as Illinois, Indiana, and Michigan, is in great part composed of earth brought by stranded icebergs, and here and there may be found in the mass of this transported soil enormous blocks of granite, which once belonged to the Laurentian Mountains, or to some other rocky chain in Canada.

Thus the effects of the ancient glacial period are still perfectly visible in the plains of the New as well as of the Old World. These are, in fact, the spots where we should expect to find the traces of former glaciers; but even warmer countries exhibit on their mountain sides and in their gorges most distinct traces of ancient ice-currents. Thus, Hooker noticed at the base of the Himalayas the remains of old *moraines* forming actual barriers across the valleys. In Syria, also, he felt justified in stating that the celebrated cedars of Lebanon grow on masses of *débris* of the same nature. At the foot of the Sierra Nevada, of Santa Marta, on the coast of Columbia, where the mean temperature is 80° Fahr., masses of *débris* are also found that the ice, which then descended 1,300 feet lower than it now does, pushed in front of it to the very sea. Lastly, Agassiz has likewise recognised the track of ancient glaciers in Brazil, not far from Rio de Janeiro, and even under the Equator, at the mouth of the Amazon. In fact, the reef of Pernambuco and the whole of the adjacent coast are nothing but a long series of *moraines* beaten and consolidated by the waves. Every region of the globe has, therefore, had its glacial period. But was this period coincident in all the various regions of the globe, or did it fluctuate from one hemisphere to the other, prevailing at one time on the north, and at another time south, of the Equator? We cannot tell; it is, however, probable that a rhythmical fluctuation of temperature took place during the lapse of centuries from one pole to the other, and that consequently the glacial periods have alternated in Europe and Africa, and in North and South America. According to Hochstetter, New Zealand and Patagonia, where the ice descends so low, are now passing through their glacial period. There are, however, hypotheses in abundance in respect to the extension of the ancient glaciers, and on this point generally geologists are still very far from agreeing on any common theory.

Fig. 90.—Ancient Glacier of Yangma, in the Himalayas; after Hooker.

CHAPTER XXXVII.

SECONDARY PART TAKEN BY GLACIERS IN THE CIRCULATION OF WATER.—MOUNTAIN FLOOD-WATERS.—ABSORPTION OF RAIN AND MELTED SNOW BY THE EARTH, PEAT-MOSSES, AND ROCKS.—SPRINGS AND THEIR NYMPHS.

EXCEPT in the polar regions, only a very small portion of the atmospheric waters becomes fixed in glaciers, to remain lying on the mountain sides for years or even centuries. The proportion of water which falls from the clouds in a liquid form is much more considerable, and consequently plays comparatively a much more important part in the economy of the globe. Rain and melted snow, being incomparably more active than ice in its circulatory movement, either flow away at once on the surface as rivers, or disappear into the depths of the rocks, whence they will gush out at some distant spot in the form of springs, or will perhaps continue their subterranean course as far as the abysses of the ocean.

In mountain gorges where the ground or bare rock will not allow the rain and snow-water to sink in, the stream runs down rapidly towards the plains, carrying with it along the bottom of its bed the *débris* which is washed away from the slopes. After an exceptionally heavy rainfall, it is often difficult to form any clear distinction between one of these temporary torrents, a fall of rubbish and mud, or an avalanche. In this case, the masses of half-melted snow, mixed with liquid mud, are hurried on by their own weight and slide down the slopes, driving before them heaps of loose stones and rubbish. The whole semi-liquid body very soon sinks down into the ravine which forms the channel of descent. The water and dirty snow are mingled in one dark and miry mass, in the midst of which rocks and stones bound about as they roll along ; in this moving chaos, the fragments of *débris* are constantly coming into collision with a crash that shakes the rocky banks, whilst the flow of the torrent tears away their base. In many places, these enormous masses totter in their turn, and soon participate in the immense downfall. A noise like thunder is the harbinger of the avalanche, and announces it from afar to any persons that may happen to be in its line; but these phenomena, which are at the same time both earthfalls and avalanches, last but for a very few instants. The torrent carries away with it and tosses about like pebbles enormous rocks 30 feet square, and when it has passed away it leaves nothing behind but thick layers of mud.

If all soils were absolutely impervious, there would be no springs, and the whole of the liquid mass furnished by rain and snow would flow away over the surface of the ground, like the torrents and flood-waters of the mountains. The greater part, however, of the water which falls upon the ground sinks in the first place into the

depths of the earth. There it becomes more or less perfectly purified from the foreign bodies with which it was charged, gradually rising to the temperature of the strata through which it passes, and becoming impregnated with the soluble salts which it meets with. Ultimately, when the water, in sinking down, encounters impervious beds, it can penetrate no farther, and flowing laterally to the outcrop of the beds, makes its escape in the form of springs.

The absorption of the rain and melted snow takes place in various ways, according to the nature of the soil. Ordinary vegetable earth only allows the water to penetrate to a very slight depth, especially when the rain falls in showers and the slope of the ground is favourable for drainage. As mould is capable of absorbing a very large quantity, indeed more than half its own weight, it prevents the strata beneath from receiving their due share of moisture, retaining almost the whole of it for the use of the vegetation which it nourishes. In fact, it requires an altogether exceptional rainfall to saturate any ordinary arable soil to the extent of a yard below the surface. Water passes with much more facility through sandy and gravelly beds; but compact loams and clay will not allow it to penetrate through them, retaining it in the form of pools or ponds on the surface of the ground.

The action of vegetation is not confined merely to absorbing the water falling from the clouds; it often, also, assists the superabundant moisture in penetrating the interior of the ground. Trees, after they have received the water upon their foliage, let it trickle down drop by drop on the gradually softened earth, and thus facilitate the gentle permeation of the moisture into the substratum; another part of the rain-water running down the trunk and along the roots at once finds its way to the lower strata. On mountain slopes, the mosses and the freshly growing carpet of Alpine plants swell like sponges when they are watered with rain or melted snow, and retain the moisture in the interstices of their leaves and stalks, until the vegetable mass is thoroughly saturated, and the liquid surplus flows away. Peat-mosses, especially, absorb a very considerable quantity of water, and form great feeding reservoirs for the springs which gush out at a lower level. The immense fields of peat which cover hundreds and thousands of acres on the mountain slopes of Ireland and Scotland, may, notwithstanding their elevation and inclined position, be considered as actual lacustrine basins, containing millions of tons of water dispersed among their innumerable leaflets. The superabundant water of these tracts of peat-mosses issues forth in springs in the plains below.

Rocks, like vegetable earth, also absorb water in greater or less quantities, according to their fissures and the density of their particles. If the soil is formed of volcanic scoriæ, or porous beds of pebbles, gravel, or sand, the water rapidly descends towards the underlying strata. Some of the harder rocks, especially certain kinds of granite, absorb but a very small quantity of water, on account of the small number of their clefts; others, on the contrary, as most of the calcareous masses, imbibe every drop of water which falls on their surface. There are some rocks which have their layers broken and cracked to such an extent that they resemble enormous walls of rubble-work; the rain instantly disappears on them as if it had fallen into a sieve. But the greater part of the calcareous rocks belonging to various geological periods is formed of thick and regular strata, cleft at intervals by long vertical crevices. Below the surface-beds, perhaps, are layers of soft marl, which the water penetrates with difficulty, although it can soften and carry away its particles. Here are formed, rill by rill, the subterranean rivulets which ultimately spread all over the substratum of marl, following the general slope of the bed. After a more or less considerable lapse of time, the strata of marl

ultimately become saturated, and the water then flows out through caverns which are variously modified by subsidences—faults in the strata and the perpetual action of the streams. The springs which proceed from calcareous rocks of this nature are in general the most abundant, owing to the length of their subterranean course. The water which falls on vast areas on the surface of plateaux is ultimately united in one bed. A liquid mass of this kind, which springs up suddenly into sight, just as if it merely issued from the soil, drains perhaps an extent of country of many hundreds or thousands of square miles.

Thus, according to the nature of the rock on which the rain falls, the latter finds its way again to the surface, either at a considerable distance from the spot where it fell, or else springs out in little rivulets immediately below the place where its drops were first gathered. On a great many mountains we are surprised to meet with springs gushing out at a few yards from the summit. These jets have, indeed, often been considered as the evidence of some miraculous intervention. Among others, we may mention the "Sorcerers' Spring," which gushes out on one of the highest points of the Brocken, the culminating peak in the Hartz Mountains. The position of this spring is, in reality, 19 feet lower than the highest part of the terminal plateau, and it has been calculated that if it served as the drainage outlet for all the rain falling on the top of the mountain, it might well supply rather more than a gallon and a half a minute. Now, as a matter of fact, it scarcely furnishes a third of this quantity. It is, however, but very rarely that it altogether fails, and instances of this have been seldom recorded. In the principal islet of the Chausey group, which is only 770 yards long by 275 broad, there is also a constant spring, and the question is whether the rain which falls on this rock is sufficient to supply the fountain, or whether it is fed by the filtration of water from the neighbouring continent. The valleys which lie at the mountain foot, or even the plains that border on less important heights, are, however, the principal spots where springs gush forth in the greatest number. Springs form a special charm in those unassuming landscapes in which nature develops all its beauties within a restricted space. Standing on the bank of some little brook which bubbles as it glides along, lending, as it were, to nature an almost articulate voice of kindness, the eye embraces a graceful *ensemble* which can hardly fail both to charm and soothe. Almost involuntarily a feeling seems awakened within us of living sympathy with the objects around, all of which appear as if made to harmonize with man's condition. The spectator feels softened, and is not oppressed and bewildered with admiration as when surveying a mighty cataract, a glacier, or the waves of the sea. Besides, can we look upon even a tiny spring without an instinctive feeling being stirred up within us that in it we see the real fountain-head of all civilization? In this little corner of the earth everything is arranged as heart could wish for the needs of the first husbandman. There are overhanging trees to shade him, a hillock to shelter him from the rude wind, pure water for his garden, and stones to build his hut. What more could he require ere he commenced those great labours in the improvement of the earth which have made us, his descendants, what we now are?

If a *blasé* inhabitant of our cities is unable to contemplate a spring without some degree of poetic feeling, how much more vivid must this sentiment have been among our ancestors who lived in the very bosom of nature! Some ancient nations, indeed, worshipped fountains as if they were divinities. The Greeks, who knew so well how to ascribe even to inanimate objects a fellow-feeling both in their passions and in their joys, have given a personality to each of their foun-

tains, transforming them into some graceful nymph or some glorious demi-god. Travellers cannot refrain from astonishment when they perceive the humble springs of Hippocrene or Castalia, and the mere rivulets of the Scamander, the Alpheus, the Ilyssus, or the Eurotas, on which the poets of Greece have conferred such imperishable glory. What! they cry, are these miserable streams the fountains and rivers that the Hellenes honoured with statues and temples? Are these slender crystal rivulets, gliding among the rocks, the objects which were invoked as patrons for powerful cities, and were sung of in their poetry in almost divine rhapsodies? These springs seem very trifling things to us—to us barbarians of the north, who only know how to appreciate the colossal, and reserve all our admiration for great rivers, such as the Mississippi or the Amazon. Yet who can ever adequately describe the ineffable beauty of the smallest spring, no matter whether it flows between two flowery banks under the mysterious shade of overhanging trees, or slowly trickles from a dark grotto under white chalky rocks, or jets up in glittering pearls from a pebbly bed, dancing the grains of sand on its tremulous drops. Each fountain has its own special character of grace or stern beauty. One is the charming Acis, escaping from the lava rocks under which the Cyclops wished to overwhelm him; another is the nymph Arethusa, swimming under the sea so as not to mingle her blue water with the troubled wave; another, again, is the virgin Cyane, bathing the flowers which she once gathered to weave a coronet for Proserpine.

CHAPTER XXXVIII.

VARIATION IN THE DISCHARGE OF SPRINGS.—ESTAVELLES.—EQUALISATION OF THE SUPPLY IN SPRINGS WITH DEEP SOURCES.—INTERMITTENT SPRINGS.

IT may be stated generally that the discharge of a spring varies according to the quantity of rain. After an extraordinary rainfall, all springs have a tendency to increase and overflow, with the exception of those which, owing to the form of their subterranean bed, are unable to yield any more considerable body of water. It sometimes happens that, during exceptionally rainy seasons, springs gush out from rock-crevices which are almost always dry, and form temporary rivulets. These are called *fontaines de disette* (scarcity springs), *fonts famineuses* (famine springs), or *bramafans* (hunger cries). The farmers very justly look upon their appearance as the formidable foreboding of a year much too wet for their crops.

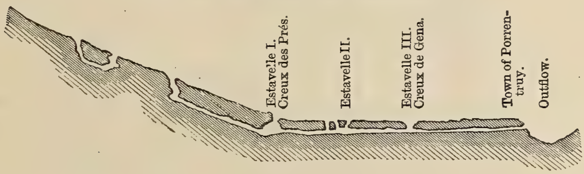
With regard to springs of a permanent character, there are a considerable number which, issuing from a rock which is split and rent in every direction, form supplementary orifices after any great amount of rain. Among the mountains, we may often notice that walls of rock which in ordinary seasons have little rivulets of water trickling along their base, will, in a rainy season, be enlivened by cascades dashing down from various heights of the jointed face. In gorges, and on gently inclined slopes, phenomena of the same nature are developed; but in some cases it is difficult to recognise the intimate connection which exists between the various springs which rise at different intervals of space along the same valley. In fact, at first sight, one can hardly understand how a temporary flow of water, gushing out a mile or two above a constant spring, can, nevertheless, be connected with the same subterranean stream, and so form only a kind of waste-valve for the lower orifice. In Languedoc these supplementary flows are called *estavelles,* a term which has been recently introduced by M. Fournet into scientific language.

The calcareous slopes of the Jura present some remarkable instances of *estavelles,* among which those in the environs of Porrentruy are specially worthy of notice. For copious springs, which rise in the town itself, are the outlets of a subterranean watercourse fed by the mountains rising to the south-west. Owing to certain depressions in the ground, and to the sound of underground currents which are here and there heard, the concealed stream may be easily traced as far as the well, or *creux* (hollow), of Gena, about two miles and a half from the town, situated at the foot of a hill. In a general way, all that can be seen at the bottom of the hole is a little stream of water making its way down towards the valley; but after

heavy rain or a rapid thaw of snow, the water bursts up with a roaring noise from the subterranean cavities, and, pouring furiously into the meadows, spreads over the surface of the ground, and ultimately runs down to the town of Porrentruy. Beyond this *estavelle*, where several subterranean watercourses unite, the slope of the valley becomes more and more steep, and other wells or *creux* of the same kind are seen, from which the overflowing water of the stream beneath temporarily issues. Higher up still, the escarped ravine of Rochedor commences, where during the whole year, the rivulet, running sometimes below and sometimes above the surface of the ground, passes through a series of chasms. At one place it springs up suddenly to the top of the rocks, and then as suddenly disappears, only to gush forth again some distance down the ravine.

The *estavelle* which is the most remarkable in France for its abundant flow of water during the rainy seasons is situated, like the springs of Porrentruy, on one of the slopes of the Jura. It is called the Frais-Puits, and rises at the opening of a little valley about two miles and a half south-east of Vesoul. In ordinary seasons, a spring of some importance—that of Champdamoy—is the sole outlet for all the rain that falls in the basin; but when the subterraneous caverns are not capacious enough to contain the whole of the accumulated liquid mass, it flows out through the orifice at Frais-Puits, about a mile and a quarter above Champdamoy

Fig. 91.—"Estavelles" of Porrentruy.

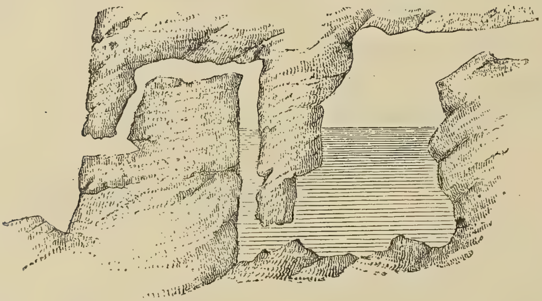


Sometimes, indeed, it is a perfect river which rushes forth from this abyss. It inundates the meadows of Vesoul over an extent of several square miles, and floods the little stream in the valley, influencing even the Saône, which receives the surplus of the sudden overflow. The Frais-Puits, in conjunction with another *estavelle*, a tributary of the Vesoul stream, has been known to discharge the enormous quantity of 133 cubic yards of water per second, equivalent to double the liquid mass of the Seine at its passage under the bridges of Paris.

We thus see that very heavy rain has the effect of causing springs to gush forth in spots where, in a general way, they do not exist; but we must also notice that every precipitation of moisture, even the most inconsiderable, has its proportional influence on the discharge of fountains and springs. The nightly freezing of melting snow, the increasing intensity of the solar rays, the intermittent activity of the phenomena of evaporation taking place on the surface of the soil, in fact, every meteoric agency, incessantly tends to modify the action of water springing forth from the earth, and causes it to change every day, and even every hour. It must, however, be understood that springs are all the less subject to the influence of the rain, sun, and wind, the farther the subterranean streams have travelled, and the deeper they have descended into the bowels of the earth. All the hindrances which the percolating water is subject to from the friction of its liquid particles against the rocky sides of its underground course, and all the delays which it is forced to

submit to in the cavernous lakes have this result—that the sudden variations which the changes of the seasons cause on the surface of the ground are modified and weakened in these subterranean beds. Down in these depths the seasons seem to blend one into the other, and their effects are mutually counterbalanced. Owing, therefore, to the long and winding channels which feed them, springs are able, as it were, to regulate themselves, and to furnish during the whole year a supply of water which varies but very slightly. In a certain number of thermal springs rising from fissures which descend to a very considerable depth in the earth's crust, the equilibrium of the liquid mass is so perfectly established that any variation answering to the different seasons can scarcely be perceived. There are, however, certain hot wells, replenished from reservoirs with which they find rapid and easy means of communication, which show a great variety in the amount of their discharge, according to the quantity of rain or snow which has fallen in the country. Thus, in July, 1855, after a long succession of stormy weather, the hot wells at Pfeffers, in Switzerland, sprung out in such abundance, both from their usual source and also from several other clefts in the rock, that they were obliged to let a great quantity of the water flow away into the Tamina without making any

Fig. 92.—Section of an Intermittent Spring.



use of it. The following year, on the contrary, the hot wells received such an inconsiderable supply that it was feared that they would dry up altogether.

The springs which cause the most astonishment are those which for a time flow plentifully, and then all at once cease running, but, after an uncertain lapse of time, again make their appearance. One might almost fancy that some invisible hand alternately opened and shut the secret flood-gate which gave an outlet to the subterranean stream. The cause of this phenomenon of intermission is easily explained. When the water brought by the underground stream is collected in a capacious cavity in the rock which communicates with the exterior surface through a siphon-shaped channel, the liquid mass gradually rises in the stone reservoir before it rushes out into the air. It is necessary that the reservoir should be filled up to the level of the siphon, in order that the latter should be primed, and that the water should flow out as a spring into the external basin. If the water in the reservoir is not replenished with sufficient rapidity, and is unable to keep at least on a level with the external outlet, the jet of water will immediately cease, and cannot recommence until the upper part of the liquid mass has again risen up to the highest point of the siphon. After an indefinite period of repose, the spring then enters on a new phase of activity.

The comparative durations of the intermissions vary according to the capacity of the retaining reservoir, the height and the diameter of the siphon, the position of the outlet-channel, the abundance of the subterranean water, and the force of the evaporation. Nevertheless, the action of each spring is incessantly modified by the frequency or scarcity of rain, and the jet of water increases or shortens the duration of its appearance. Occasionally springs which are generally intermittent are recruited by subterranean channels to an extent sufficient to enable them to flow without interruption for weeks or whole seasons. At other times, after long periods of dryness, the spring entirely ceases to gush out; and the visitor who, on the faith of some old book, stands waiting, watch in hand, for the predicted appearance, runs a good chance of gazing vainly for many a long hour upon the dried-up basin of the fountain. It also often happens that the fall of rocks, or the opening of fresh clefts, alters the course of the subterranean stream and destroys its periodicity. Thus, the Bullerborn, a spring in Westphalia, which at one time burst out of the ground about every alternate four hours with sufficient force to turn the wheels of several mills, has, since the commencement of the eighteenth century, become a perennial but less copious stream than formerly.

CHAPTER XXXIX.

ASCENDING SPRINGS.—ARTESIAN WELLS.—TEMPERATURE OF JETTING SPRINGS.

THERE are many of these subterranean streams which, before they break forth in springs, do not flow over beds continuously sloping in the direction of their current, as is the case with watercourses on the surface of the ground. There are some indeed which first descend into the bowels of the earth, either by a uniform declivity, or by a series of cascades or rapids, and ultimately reascend from the depths towards the surface, or jet out vertically from the ground. Let us follow in our imagination a rill of melted snow trickling down from the mountain-side through the crevices of the earth, to a depth of some hundreds or thousands of yards below the surface of the ground. So long as this water does not meet with any impervious stratum, it continues to sink towards the lower abysses. But if its progress is arrested by a bed of retentive clay or any other layer through which it cannot pass, it will spread out over this layer, and will follow all its inflections. Should this stratum curve gradually upwards towards the surface of the ground, or should it even rise suddenly, the subterranean stream will reascend, as if in a tube, so as to place itself in a position of equilibrium with the other liquid masses which continue to descend from the heights.

Added to this, in obedience to the law which compels liquids to seek the same level in all connected reservoirs, a rivulet of water will never fail to dart forth as a spring as soon as it finds an outlet below the caverns in which the water is collected from which it proceeds. Likewise, if the spot where it gushes forth is on a much lower level than that of the feeding reservoirs, the liquid jet must necessarily shoot up in a column above the surface of the ground. This is the case at Châtagna, in the department of the Jura, where a natural jet springs up to a height of 10 or 12 feet. In the grotto of Male-Mort, near Saint-Etienne, in Dauphiné, the jet is not less than 23 to 26 feet in height. But the water of the fountains being always more or less charged with sediment, the deposit accumulates in the form of a circular hillock round the orifice, thus almost always ultimately raising it to the level of the top of the liquid column. As an instance of these rising fountains, we may mention the famous springs of Moses (*Aïn Musa*), which gush out in a charming oasis not far from the shores of the Gulf of Suez. These springs, the temperature of which varies from 70° to 84° (Fahr.), now flow from the top of several small cones of sandy and slimy *débris* which they have gradually thrown up above the level of the plain. They are also shaded by olive and tamarind trees. At a certain distance from the spot where these small streams gush out, there is a line of dried-up cones. These are the former

fountain-heads, which are now abandoned by the water on account of their too great elevation.

This phenomenon of the springing up of deep-lying water from the bowels of the earth is a fact established beyond all doubt by direct observations; for, many centuries ago, the absolute necessity of finding springs of water in arid countries disclosed to the nations inhabiting them the existence of these sources ascending from the depths of the earth. In the deserts of Egypt and Algeria the natives, from the most remote antiquity, had learnt how to bore wells 30, 40, and even 90 feet into these liquid veins, and thus, in the very midst of the sands, they caused the rising columns of water to spout out, casting life and riches all around them. The inhabitants of certain valleys in Afghanistan and Arabia, fearing to lose a drop of the precious water which comes down to them from the mountains, have had the foresight to take possession of the brooks at their issue from the gorges, and to enclose them in subterraneous tunnels, inclined according to the general slope of the soil. The water thus protected from the heat of the sun does not evaporate at all *en route;* it reaches the foot of the declivity almost without waste, and, ascending by a vertical well into the outlet-reservoir, flows immediately into the irrigation trenches. The greater part of these channels are pierced here and there with apertures, through which the cultivators of the banks of the river draw the water necessary for their crops. Some of these subterranean streams are not less than 36 miles in length. They are rudimentary imitations of the very work which nature herself accomplishes in order to elaborate her springs, and cause them to gush out from the surface of the soil.

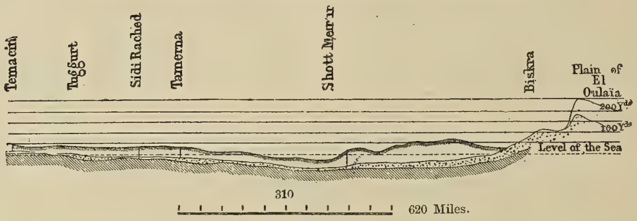
Thanks to the efficacious means of boring which modern ingenuity has placed in the hands of geologists, men do not now content themselves with piercing the beds of clay, sand, and stone to any trifling depth, but penetrate hundreds of yards, in order to give an upward egress to the veins of water which have descended from mountains or distant plateaux. By means of the second-sight which study gives him, the *savant* can point out beforehand with almost perfect precision the course of the subterranean waters, and even the quality of the fluid. Thus the engineers bored through the soil in the environs of Calais in the hope (which was justified by the result) of touching upon the waters which had come from the hills of England under the Straits of Dover, and making it spring up in their wells. They have also dug with perfect confidence in the precise spot where saline or medicinal waters flowed under the ground. In the Algerian Sahara, the engineers mark beforehand in the middle of the barren and arid desert the place where an abundant spring ought to gush out, and every blow of the boring-rod brings to the surface a jet of water which is soon surrounded by tents and the budding palm-trees of an oasis.

Thus, although the sight of man cannot penetrate through the beds of rocks piled one above another, yet the subterranean course of the streams is none the less visible to his mind's eye. Besides, these subterranean waters act exactly in the same manner as those which flow on the surface of the soil; they also carry along their alluvium, and thus contribute their part towards modifying the relief of the globe. In many places, especially at Tours, the artesian wells have ejected the remains of plants, branches, moss, snail-shells, and other *débris* which the rains had probably carried away some weeks previously into the depths of the earth. At Elbeuf, the water of a well contained living eels.

Many artesian wells reach a very considerable depth. The celebrated well of Grenelle is not less than 1,771 feet deep, and the water which rises from the bottom

of this abyss also ascends 91 feet. The salt water which rises from the artesian spring of Neusalzwerk, near Minden, proceeds from a depth of 2,394 feet. A spring of sulphureous water at Louisville, in Kentucky, rises in a bore 2,086 feet deep, and the water leaps up 170 feet from the orifice. A well dug at Saint Louis, on the Missouri, to supply a sugar refinery, exceeds 2,624 feet in depth. The quantity of water which it is possible to obtain from the various borings is very considerable, and, in many cases, would be still larger if the ascending tubes had a wider diameter. The spring of Neusalzwerk yields 321 gallons a minute; an artesian well of the Wed R'ir, that of Sidi-Amran, supplies in the same space of time 884 gallons, or 5 cubic yards. That of Passy, at Paris, yields 7 cubic yards. In some spots, a large number of artesian wells unite into one single rising column

Fig. 93.—Artesian System of Wed R'ir; after Dubocq.



the waters of two or more sheets of fluid lying one above another. Thus at Dieppe, in boring a well 1,092 feet in depth, they came successively upon seven very abundant water-bearing strata.

In all artesian springs, the temperature rises the farther the well descends below the level of the sea. The jet from the well of Grenelle marks 82° (Fahr.), 64° (Fahr.) more than that of Passy; that is to say, that at this point of the terrestrial crust, the increase of heat is 1° (Fahr.) for each interval of 55 feet in depth. The thermometrical study of other artesian springs has given results differing little from this, and it can be strictly stated that for every space of from 40 to 55 feet of vertical height, the temperature increases on an average 1° (Fahr.) from the surface of the soil to the lowest beds which the excavations of man have yet penetrated. In the springs of the Sahara the increase of temperature is, according to M. Ville, 1° (Fahr.) to 36 feet of depth.

CHAPTER XL.

COLD AND THERMAL SPRINGS.

AS artesian wells only differ from natural springs in the change of direction given to their waters, the same laws must apply to all subterranean currents; consequently the depth to which the water descends into the bowels of the earth may be approximately ascertained by the temperature of a spring. It may be confidently affirmed that, in a general way, cold springs, that is to say, those the mean temperature of which is lower than the heat of the soil, descend from mountains, and that thermal springs proceed, on the contrary, from beds lying deep in the interior of the earth.

In the innumerable multitude of springs, either cold or thermal, which rise from the earth, we may observe the whole range of possible temperatures from freezing-point up to the boiling-point. A spring which flows from the sides of the Hangerer, in the Œtzthal, at a height of 6,742 feet, is only 1° warmer than ice. On the Alps, the Pyrenees, and all the other chains of snow-clad mountains, near the summits small rills of water are very frequently met with, the temperature of which is scarcely higher than that of melting snow. Even at the bases of mountains, and especially those of a calcareous nature, a great number of springs are found which are much colder than the surrounding soil. Geologists who have applied themselves to the study of subterranean hydrography, have had many opportunities of proving the truth of the fact that drainage-waters at first maintain a temperature considerably lower than that of the rocks. This is so, because, in addition to the water, the air also enters the subterranean channels and circulates in all the network of clefts and crevices, and by incessantly gliding over the wet sides of the channels produces a rapid evaporation of moisture, and, in consequence, refrigerates the surface of the rocks and even the stream itself. The temperature, therefore, of springs which proceed from the interior of cavernous mountains is always several degrees lower than the normal temperature of the soil.

The greater number, however, of subterranean rivulets which flow at a small depth below the surface of the rocks or earth, and gush forth in springs after having slowly traversed a slightly inclined extent of ground, ultimately acquire a temperature scarcely differing at all from that of the soil. The simplest means of approximately ascertaining the mean temperature of any particular spot is to plunge the thermometer into the spring-water; for as the extremes of heat and cold are inoperative at a depth of only a few yards below the surface of the soil, the greater number of liquid veins are not liable to the changing influences of the outer air,

and, in consequence, show at their emerging point the real average climate of the locality. In winter the Sorgue of Vaucluse seems to smoke, on account of the rapid condensation of its vapour, which is cooled by the atmosphere. During the severe winter of 1819 to 1820, when the Rhone was completely frozen over, and might be safely crossed from Avignon to Villeneuve, M. F. de Lanoye tells us, the whole extent of the Sorgue remained perfectly free from ice.

Springs which have a higher temperature than the soil are called *thermal* springs. These are the springs the depth of which may be roughly estimated by calculating a descent of 55 feet for each degree (Fahr.) beyond the normal heat of the surrounding soil. Thus the springs of Plombières, which have a temperature of 149° (Fahr.), would take their rise 5,413 feet below the surface; those of Chaudes-Aigues, the heat of which is found to be not less than 178° (Fahr.), issue from beds situated 6,889 feet from the surface of the soil; lastly, the gushing rivulet of Trincheras, in Venezuela, which marked 206° (Fahr.) at the time of Boussingault's visit in 1823, would proceed from rocks at a still more considerable depth.

It has been the subject of direct observation in the well of the Geysers, in Iceland, that the deep water in the interior of the earth may attain a temperature considerably above 212° (Fahr.); but on reaching the surface, this boiling water, nearly all of which jets forth in the vicinity of volcanoes, must necessarily be transformed to steam. It should also be remarked that the high temperature of several springs is owing to accidental causes. When the volcano of Jorullo made its appearance in 1759, two small rivulets—the *rios* of Cuitimba and San Pedro—were covered with intensely heated scoriæ, and reappeared farther down their course as thermal springs. In 1803 the lava was still warm, as the temperature of the springs measured by Humboldt exceeded 149° (Fahr.); but travellers who have recently visited the district of Jorullo aver that the water flowing from the base of the volcano has gradually cooled since the commencement of the century, and that soon it will have reached the normal temperature of the surrounding soil. In the same way the water of Bertrichbad, in Luxembourg, has gradually discontinued to be either warm or mineral in its character ever since the lava of a small eruption has ceased to come in contact with the burning furnace which produced it.

It is to be remarked that nearly all thermal springs which do not owe their high temperature to the vicinity of volcanoes issue forth from vaults which open on the surface of masses of a crystalline nature, and principally at the side of modern eruptive rocks which have been thrust up through older strata. This must evidently be the case, for in piercing the terrestrial crust the upheaved matter has broken through the parallel layers which detained the sheets of water, and by this rupture of the strata has opened channels by which the springs can ascend towards the surface of the soil. One fact, also, that proves the existence of these deep fissures whence thermal waters spring, is that their temperature sometimes changes suddenly, in consequence of earthquakes which obstruct the former faults or else open them out to far greater depths. At the time of the earthquake at Lisbon, the temperature of a spring of Bagneres-de-Luchon suddenly rose, *it is said*, from 46° to 122° Fahr. (?), and since that date, now more than a century ago, the action of the spring is not modified. It is also said that the thermal springs of Bagnères-de-Bigorre suddenly became cool at the time of the great earthquake in 1660.

The influence of rains and seasons have much less effect upon thermal waters than upon cold springs which proceed from the upper layers of the soil. A great

number of warm springs, however, undergo certain changes in their yield of water, which must be, without doubt, attributable, at least partially, to the same causes as the variations in the discharges of superficial streams. In Auvergne, in the Pyrenees, and in Switzerland, several springs, perfectly protected against any infiltration of rain-water, flow in much greater abundance at the very same period when the adjacent torrents become swollen. It is true that the increase of thermal water must be partly caused by the lateral pressure exercised by the cold waters saturating the soil and forcing back all the small scattered rills towards the central spring. But the liquid mass proceeding from deep beds is also much stronger (for the temperature of deep springs increases simultaneously with the yield), doubtless because the subterranean rivulets, when increased in volume, are less retarded in their course, and lose less heat in mounting towards the surface of the ground. At Brig-Baden, in the Valais, the water, the mean temperature of which is in autumn and winter from 71° to 72° (Fahr.), rises 113° and 122° (Fahr.) when the breath of spring melts the ice on the Jungfrau. Many of the phenomena, however, exhibited by thermal springs are still rather difficult to explain. The greater number, therefore, of *savants* who devote themselves to the study of subterranean hydrology admit that the tension of gases which are produced in the interior of the earth plays a principal part in the emission of thermal waters.

Most thermal springs contain mineral substances in solution; there are, however, a certain number which are almost as pure as rain-water: such as, for instance, the celebrated waters of Plombières, which do not even contain $\frac{1}{3300}$ of salts; also those of Gastein, Pfeffers, Wildbad, and Badenweiler. The springs of Chaudes-Aigues—those in France which have the highest temperature, 158° to 176° (Fahr.)—contain only a small amount of mineral substances. The inhabitants of Chaudes-Aigues use the water to prepare their food, to wash their linen, and to warm their houses. Wooden conduits, erected in all the streets of the town, supply, on the ground-floor of each house, a reservoir, which serves to heat it during cold weather, and thus dispenses with fires and chimneys. In summer, small sluices, placed at the entrance of each conducting tube, stop the warm water, and throw it back into the rivulet which flows at the bottom of the town. Berthier, the chemist, has calculated that the heat furnished daily by the springs is equal to that which the combustion of more than four tons and a half of coal would produce. It is sufficient to give a comfortable temperature to the interior of the houses and to warm the streets themselves. The snow, which falls in great abundance during winter, melts immediately after its fall. There are not, perhaps, in the world any thermal springs the heat of which is better utilised.

CHAPTER XLI.

MINERAL SPRINGS.—INCRUSTING SPRINGS.—METALLIC VEINS.—SALT SPRINGS.

SPRING-WATER, cold as well as hot, is rarely, if indeed ever, pure from all admixture; thousands of samples analyzed even in our time by chemists do not furnish a single instance of spring-water which does not contain a greater or less proportion of calcareous or magnesian salts. The purest water that the French chemists have yet found is that of the Dorne, a small river of Ardèche, and this may almost be compared to distilled water. In the other mountainous regions of Central France, water, considered quite excellent in its character, is charged with two, three, four, or even ten times more calcareous matter. The water of the Seine contains on an average thirty-six times more extraneous matter, and some wells at Paris and Marseilles, the water of which is, notwithstanding, used for drinking, are 250 to 350 times less pure.

Among the various substances which spring-water brings to the surface, those which are most common proceed from the strata which serve to constitute the very framework of the globe. Chalk, especially, occurs in different proportions in most springs, either under the form of sulphate of lime or, more often, as carbonate of lime. Water which contains carbonic acid in solution is charged with calcareous matter dissolved away from the sides of the rocks through which it passes; then, by means of evaporation, it redeposits the stony substances which it previously held in solution. Hence arise all those calcareous concretions which form around so many springs; also the stalactites in caverns, and even those dangerous incrustations which accumulate in the boilers of locomotives.

Nearly all countries of the world possess some of those curious springs, which cover with a calcareous crust any object placed in their waters. Among these incrustating springs, those of Saint-Allyre, near Clermont, Rivoli, and San Filippo, not far from Rome, have justly become celebrated. These latter have, in a space of twenty years, filled up a pond with a bed of travertin 30 feet thick, and, in the neighbourhood, entire strata of this same rock may be seen having a depth of more than 328 feet. The springs of Hammam-Mes-Khoutine, in the province of Constantine, are also very remarkable on account of the considerable amount of their deposits. This water, which rises at a temperature of 203° (Fahr.), and from which a high column of steam always rises, is frequently compelled to change its point of issue on account of the dense beds of travertin which are gradually deposited upon the soil. Most of these deposits are of a dazzling white hue, striped here and there with bright colours, and are developed in mammillated strata; other concretions,

accumulating gradually round an orifice, have taken the form of cones, and are like the small craters near a volcano, some of them rising to a height of as much as 33 feet; lastly, there are masses of travertin which stretch out in a kind of wall below the flow which deposits them. One of these walls, which is interrupted at intervals by heaps of earth upon which large trees grow, is not less than 4,921 feet long, 66 feet high, and, on an average, from 33 to 49 feet wide.

The thermal waters of Algeria are, however, surpassed in grandeur and beauty by the springs of the ancient Ionian city of Hierapolis (holy city), which, at the present time, flow in the solitary plateau called Panbouk-Kelessi (Castle of Cotton), on account of the cotton-like aspect of the white masses of travertin of which it is composed. On reaching this spot from Smyrna, something like an immense cataract may be seen in the distance, 328 feet high and $2\frac{1}{2}$ miles wide; this is

Fig. 94.—Natural Bridge of Panbouk-Kelessi; after Tchihatchef.

formed by the walls which the water has gradually constructed, column after column, and layer after layer, by flowing over the edges of the plateau and gushing out on the slopes. Here and there, real cascades glitter in the sun, and their sparkling surfaces light up the dead whiteness of the crystal walls. As a spectator ascends the declivities, the masses deposited and carved out by the water appear in all their strange beauty; one might fancy that they were colonnades, groups of figures, and rude bas-reliefs which the chisel had not yet perfectly set free from their rough coverings of stone. Amid all these calcareous deposits which have been fashioned by the cascades during a succession of ages, open a multitude of cup-like hollows with fluted edges fringed with stalactites; these graceful reservoirs —some of which are shaded with yellow, or veined with red, brown, and violet, like jasper or agate—are filled with pure water. Higher still follow two steps of the plateau on which stood the ancient thermal edifice and the necropolis of

Hierapolis. Here whitish masses cover the ancient tombstones and fill up the conduits. The ground is crossed in various directions by the former beds of rivulets, which have gradually stopped up their own courses by depositing concretions upon them. Above one of the widest of these dried-up channels, the magnificent span of a natural bridge displays its graceful form, like an arch of alabaster, streaming with innumerable stalactites. At what date did this majestic structure take its rise, and how many years and centuries did the process of its formation last? Accoring to Strabo, the channels of the baths of Hierapolis were soon filled up by solid masses, and if Vitruvius can be believed, when the proprietors of the environs wished to enclose their domain, they caused a current of water to run along the boundary line, and in the space of a year the walls had risen.

Silica, which is still more important than chalk in the formation of terrestrial rocks, is also sometimes deposited on the edge of springs, but in very small quantities; only those waters which are of a very high temperature can dissolve silica in sufficient quantities to form a deposit round their outlet, and produce beds of any considerable thickness. Among the springs which are charged with silica, the best-known are the geysers of Iceland, the boiling waters of which deposit round their orifice circular layers of siliceous concretions several yards high. Other volcanic springs are no less active, and even at a long distance from any volcano, there are few thermal springs which do not contain silica in quantities more or less perceptible.

Concretions and crystallizations formed by thermal waters in the very interior of fissures or lines of fault have geologically more importance than external deposits, and can be produced at a much lower temperature than in the open air. M. Daubrée has seen these phenomena in action at the springs of Plombières. The ancient Roman masonry which was used for storing and supplying water is filled with zeolites, or siliceous crystals, evidently owing to the prolonged influence of the water and its slow chemical reaction on the calcareous cement and the bricks. The intimate structure of these materials has been modified by this water, the heat of which does not, however, exceed 140° to 158° (Fahr.). It is doubtless a similar chemical action, due to these thermal waters, which has produced in all the fissures of Plombières the veins of quartz, opal, and fluor-spar which are found there. The enormous deposits of a quartz-like nature in an adjacent valley, that of Roches, are results of the same geological work.

It is probable that at 33,000 or 39,000 feet deep in these abysses, where the water, still in a liquid state, may attain a temperature of 500° to 600° (Fahr.), the chemical operations of subterranean waters are accomplished with much more activity than in beds near the surface. Most geologists think that thermal vapours can dissolve not only those metals which melt at low temperatures, such as tin and lead, but also copper, gold, and silver. Veins containing metals are probably only fissures in which these thermal vapours have become cooled, and have then deposited the metallic substances with which they were charged. Gold, silver, and copper, remain in the depths of the earth, and the waters bring up to the basin of the spring nothing but a small quantity of salts, silicates, and gases. Then follow the gradual movements of the crust and the geological revolutions which cause the metallic veins to rise to the level of the ground, or, at least, which bring them nearer to the surface.

Among the mineral substances which some springs bring to the surface of the soil, the most important in an economical point of view is common salt. This substance, being one of those which dissolves most readily in water, all the liquid

veins which pass over saline beds become saturated with salt; therefore springs of this kind, which flow in great abundance, give rise to salt-works of more or less importance. The masses of common salt which make their way every year from the interior of the earth may be estimated at thousands of tons. The springs of Halle, which rise on the northern slope of the Alps of Salzburg (Salt Town), and are managed with the greatest care, annually produce 15,000, tons of this mineral. The salt-springs of Halle, in Prussia, which have been worked from time immemorial by a company, furnish 10,000 tons of salt every year. Other parts of Germany also yield for consumption thousands of tons of white salt, which is produced by the evaporation of saline springs. The mass of salt furnished by the single artesian well of Neusalzwerk, near Minden, in Prussia, represents every year a cube measuring 78 feet on each side.

Though not so rich as Germany in saline springs thus turned to account, most of the civilized countries of the world possess salt-works which are also very important. France enjoys the springs of Dieuze, Salins, and Salies; Switzerland, those of Bex; Italy has the springs in the environs of Modena, and many others besides. In England, near Chester, there are some mines of rock-salt in which numerous liquid veins issue forth which are impregnated with salt. Lastly, the United States have the celebrated springs of Saratoga. But how many other saline springs, still more abundant, flow uselessly along in the solitudes of the world!

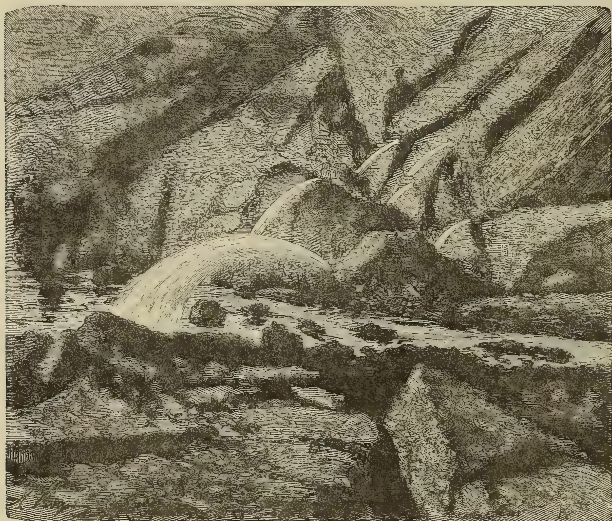
Not far from the "spot where Troy once stood" is the valley of Tuzla-su, which owes its name (Salt Water) to its numerous salt springs. The mountains which rise around its circumference are variously shaded with blue, red, and yellow, and the rocks are incessantly decomposing under the action of the liquid salt which oozes out from, and trickles down, their sides. The plain itself is covered with a variegated crust, whilst jets of boiling water, saturated with salt, burst forth in every direction. Here and there pools are found, the moisture of which, by evaporating in the sun, leaves upon the soil beds of salt as white as snow. Near the mouth of the valley springs become more and more numerous. Lastly, in the place where the cliffs approach near together, so as to form a defile, a magnificent spout of water jets out from one side of the rock. This jet is not less than a foot in diameter at the orifice, and falls again after having described a parabola of more than a yard and a half. Other springs shoot out on both sides, the constant temperature of which is more than 212° (Fahr.); these, together with the principal jet, form a rivulet of boiling and steaming water. It would be easy to extract from these springs an enormous annual supply of salt; but the negligence of the Turkish Government, which has appropriated the valley of Tuzla-su, has prevented more than one thousand tons a year being obtained.

Springs of salt water are used for the treatment of diseases as well as for the extraction of salt. They constitute one of the most important groups of medicinal waters, according to the various substances which they contain in solution. The other springs made use of on account of their healing virtues have been classed under ferruginous, sulphureous, and acidulous springs. These waters also contain, in different proportions, a variable quantity of gases and salts which they have dissolved in their passage over subterranean beds of every kind. It is probable that the proportion of gases dissolved in the water fluctuates with all the variations of temperature and pressure of the surrounding air. It even appears that a simple movement of the liquid is sufficient to alter the constituents of the water as regards its gaseous elements; but, on the whole, the chemical composition is tolerably per-

manent, and there is no doubt as to the particular virtue of every spring which renders it fit for the treatment of one or many special diseases. Thanks to this healing power, all the resources of which science, still imperfect, is yet ignorant of, medicinal waters serve as a guide to a more familiar acquaintance with nature; for thousands and hundreds of thousands of visitors are, every year, attracted by them to the most picturesque and majestic spots on the face of the earth.

In fact, mineral springs, which, for the most part, are also thermal, having flowed from deep beds, nearly all issue forth at the point of contact between older rocks and more modern formations. Now, these points of contact are especially found in mountainous countries, which also receive from the atmosphere larger quantities of water than plains do. Mineral springs are most numerous and abundant in mountain valleys, and there, consequently, the great thermal institutions

Fig. 95.—Saline Springs of Tuzla Su.



are established. In Europe the chain of the Pyrenees is probably the richest in mineral, sulphureous, saline, ferruginous, and acidulous springs. According to Francis, the engineer, in 1860 more than 550 mineral springs, 187 of which are used, flowed upon the French slopes of the Pyrenees. These waters supplied 83 hot baths in 53 localities, the principal of which are, Bagnères-de-Bigorre, Luchon, Eaux-Bonnes, and Cauterets. The most abundant springs, those of Graus d'Olette, form a sort of mineral stream, yielding more than 4 gallons a second, or 2,322 cubic yards a day. In Algeria the spring of Hammam-Mes-Khoutine yields 6 gallons a second.

There are regions, some volcanic and some not, in which nearly all the springs are thermal and mineral; springs of pure and fresh water being so rare, they are there considered to be most precious treasures. One of these regions comprehends a large part of the plateau of Utah. In this place numerous thermal springs issue

forth, to which have been given the vulgar names of the Beer, Steamboat, Whistle springs, &c., and into one of which the Mormons plunge their neophytes. The springs which are not thermal are loaded with saline and calcareous matter. It is only in spring, at the time when the snow melts, that the springs, which then become very abundant, yield comparatively pure water. During the dry season, salt and carbonate of lime become concentrated in the nearly exhausted springs, and give to the liquid flow an unpalatable taste. Palgrave, the traveller, informs us that all the springs of the country of Hasa, in Arabia, are also thermal.

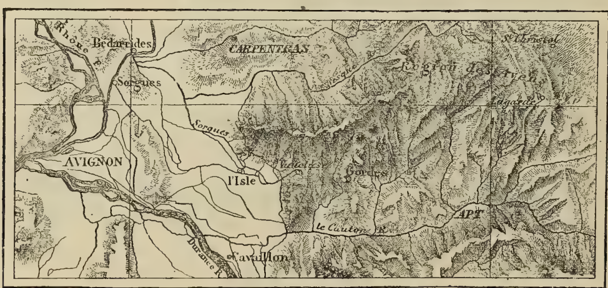
It can readily be understood that when all these substances escape from the interior of the rocks, together with the water which holds them in solution, they must leave empty spaces in the earth. During the course of long centuries, whole strata are dissolved, and, under a form more or less chemically modified, are brought up from the depths and distributed on the surface of the soil. The thermal waters of Bath, which are far from being remarkable for the proportion of mineral substances they contain, bring to the surface of the earth an annual amount of sulphates of lime and soda, and chlorides of sodium and magnesium, the cubic mass of which is not less than 554 cubic yards. It has also been calculated that one of the springs of Louèche, that of Saint-Laurent, brings every year to the surface 8,822,400 pounds of gypsum, or about 2,122 cubic yards; this quantity is enough to lower a bed of gypsum, a square mile in extent, more than 5 feet in one century. But this is only one spring, and we have reckoned one century only; if we think of the thousands of mineral springs which gush from the soil, and of the immensity of time during which their waters have flowed, some idea may be formed of the importance of the alterations caused by springs. In time they lower the whole mass of mountains, and no doubt after these sinkings violent oscillations of the earth may often have taken place.

CHAPTER XLII.

SUBTERRANEAN RIVERS.—THE SPRING OF VAUCLUSE, THE TOUVRE.—SUBMARINE AFFLUENTS.—THE RIOS OF YUCATAN.—THE "MUD-LUMPS" OF THE MISSISSIPI.

IN regions where the strata are pierced with wide and deep caverns, and especially in calcareous countries, the waters sometimes accumulate in sufficient quantities to form perfect streams with long subterranean courses. At their issue from the caverns, these waters form a contrast with the rocks and hills around, all the more striking because the latter are completely devoid of moisture, and absolutely sterile, whilst on the brink of the limpid stream the fresh verdure of plants and trees is at once developed. Like a captive joyous at seeing the light once more, the water which shoots forth from the sombre grotto of rocks

Fig. 96.—Vaucluse and the Sorgues.



sparkles in the sun and careers along with a light murmur between its flowery banks.

Among these subterranean streams, the most celebrated, and doubtless one of the most beautiful, is the Sorgues of Vaucluse. The vaulted grotto from which the mighty mass of water escapes opens at the mouth of an amphitheatre of calcareous rocks with perpendicular sides. Above the spring rises a high white cliff, bearing on its summit a ruined tower of the Middle Ages; the rock is everywhere sterile and bare; there is nothing but a miserable fig-tree, clinging to the stone like a parasitical plant to the bark of a tree, which has plunged its roots into the fissure of the cave, and greedily absorbs with its leaves the moisture

which floats like a mist above the cascades of the spring. After heavy rains, the liquid mass, which is then estimated at 26 or even 32 cubic yards a second, flows in a wide sheet high above the entrance to the cavern, which is then altogether inaccessible. When the waters are low, they flow bubbling across the barrier of rocky *débris* which obstructs the entrance; at that time, it is quite possible to penetrate under the arch and to contemplate the vast basin in which the blue waters of the subterranean stream spread out before they leap into the open air. Soon after its issue from the cave and amphitheatre of Vaucluse, the Sorgues is divided into numerous irrigation-channels, which spread fertility in the country over an area of more than 77 square miles. The subterranean course of the affluents which form the stream is not ascertained; but it is known that most of them commence at 12 or 15 miles to the east, and the plateau of Saint-Christol

Fig. 97.—Course of the Touvre

and Lagarde, which are pierced all over with *avens*, or chasms, into which the rain-water sinks and disappears.

In another part of France, there is a second important subterranean stream, which is much less known but no less remarkable than that of Vaucluse; this is the Touvre of Angoulême, continuing the course of the Bandiat, the waters of which, like those of the Tardoire, are swallowed up in several abysses at distances varying from 3 to 7 miles to the east and north-east. The three principal springs of the Touvre flow slowly out of a deep cave, hollowed out at the base of an escarped cliff; another spring bubbles up in a basin of rocks; the third emerges from a sort of boggy meadow intersected by drains. At the outlet of their subterranean courses these three enormous springs immediately form three streams, which reunite, leaving between them two long peninsulas of reeds and other aquatic plants. Below the junction, the Touvre, which is here more than 100

yards wide, passes round a rugged hill, and dividing into several branches, turns the numerous mill-wheels of the important gun-foundry of Ruelle; then, after a course of 5 miles, it flows into the Charente at a small distance above Angoulême. Among the hundreds and thousands of travellers whom steam annually conveys over the bridge of the Touvre, there are few who are aware of the curious nature of the source of the river of limpid water over which the train passes in its noisy career.

Omitting to mention the streams which accidentally pass under strata of rocks during a small part of their course, or of the subterranean outlets of certain lakes, a multitude of other instances might be brought forward of masses of water, more or less abundant, which appear above ground after having traversed a considerable distance under the earth. Of this kind is the graceful spring of Nîmes, the blue transparent water of which, reflecting the foliage of pines and chestnut-trees, glides in its gentle ripples over the semicircular steps of an old Roman staircase. Such, also, is the spring of Vénéran, near Saintes; this spring, which was formerly sacred to the Goddess of Love, gushes from the ground in a gorge of rocks, and passing through a mill, the wheel of which it turns, it suddenly disappears, being swallowed up in an abyss.

Many watercourses do not reappear on the surface of the soil after being swallowed up in the earth, but flow straight to the sea by means of subterranean channels. On nearly the whole extent of the continental shores, and principally in localities where the coasts are of a calcareous nature, the outlets of submarine tributaries may be noticed, some of which are perfect rivers. Most of the springs of the department of Bouches-du-Rhone jet up from the bottom of the sea, but at various distances from the shore. One of them, that of Porte Miou, near Cassis, forms on the surface of the sea a considerable current, which drifts any floating bodies to a great distance. At Saint-Nazaire, Ciotat, Cannes, San-Remo, and Spezzia, other streams also issue from the midst of the salt waves, and attempts have even been made to measure approximately their discharge. M. Villeneuve-Flayosc estimates at 24 cubic yards a second the quantity of water discharged into the sea by all the hidden affluents of the Mediterranean between Nice and Genoa. Some of the submarine springs of Provence and Liguria proceed from enormous depths. The orifice of the spring of Cannes is 531 feet below the level of the sea; that of San-Remo rises from a depth of 954 feet; lastly, at four miles to the south of Cape Saint-Martin, between Monaco and Mentone, another stream of fresh water empties itself under a bed of salt water, nearly 2,296 feet deep.

The coasts of Algeria, Istria, Dalmatia, and the Herzegovina also present numerous instances of submarine streams; on the eastern shores of the Adriatic the traveller may even have the pleasure of contemplating the delta of a considerable river, the Trebintchitza, visible through the sea-water at the depth of a yard. Certain streams flowing from the mainland and fed by the snows of the Liburnian plateau even converge in a submarine river, which reappears in the island of Sherso, where it forms the great Lake Vrana. The extremely low temperature of this lake removes all doubt as to its true origin either in the Istrian hills, or on the upland slopes of Monte Maggiore, or possibly on Mount Velebit in Croatia.

The abuntant springs of fresh water which pour out into the open sea to the south-west of the Cuban port of Batabano are well known, since Humboldt described them, and it is observed that the lemantins, or sea-cows, which dread salt water, delight in frequenting these parts. Lastly, the Red Sea, which does not throughout its immense circumference receive a single permanent stream flowing on the

suface of the ground, nevertheless receives some which spring from the bottom of its bed. The shores of the United States, the calcareous soil of which is probably pierced with caverns from the very centre of the continent, perhaps are the coasts which pour into the sea the most abundant subterranean rivers. Near the mouth of the stream of St. John, a subterranean stream of perfectly pure water spouts in bubbles as far as one to two yards above the level of the sea. Off the Carolinas and Florida, salt water has been known to change into brackish water under the influence of the sudden increase of its subterranean affluents. In the month of January, 1857, all that part of the sea which is adjacent to the southern point of Florida was the scene of an immense eruption of fresh water. Muddy and yellowish water furrowed the straits, and myriads of dead fish floated on the surface and accumulated on the shores. Even in the open sea the saltness diminished by one-half, and in some places the fishermen drew their drinking water from the surface of the sea as if from a well. It is affirmed by all those who witnessed this remarkable inundation of the subterranean river that, during more than a month, it discharged at least as much water as the Mississippi itself, and spread over all the strait, 31 miles wide, which separates Key-West from Florida.

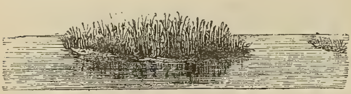
On the coasts of Yucatan, the fresh waters which take a subterranean course down to the sea do not appear to flow like rivers which have a narrow bed and attain considerable speed, but more in the form of a wide sheet of liquid with a nearly imperceptible current. *Cenotes* open here and there over the surface of the country; they are a kind of natural draining well, or hole, not very deep, into which the inhabitants descend to draw spring water. At Merida and in the environs the subterranean water is found at a depth of 26 to 30 feet; but the nearer we approach to the sea the thinner the layer of rock becomes which covers the liquid veins; on the sea-shore fresh water is found nearly on a level with the soil. The height of the veins varies several inches, according to the quantity of rain; but in every season, the mass of water descending from the plateau of Yucatan is poured into the sea through innumerable outlets. Over a great extent of the shore of the peninsula, these hidden springs furnish collectively a mass sufficiently large to counterpoise the waters of the sea. Under the pressure of the marine current which runs along the coast, there is formed, between the open sea and the liquid mass which has made its way from the land, a littoral bank like those barriers which the waves construct before the mouths of rivers. This embankment, which protects the coasts of Yucatan like a breakwater, is not less than 171 miles long, and is cut through by the sea at two or three points. The channel which stretches like a wide river between the bank of alluvium and the Yucatan coast is, not without reason, designated by the inhabitants by the name of stream, or *rio*.

Among the remarkable phenomena which perhaps owe their existence to subterranean watercourses, we must mention the sudden or gradual appearance of those hillocks of clay ("mud-lumps") which rise, to the great danger of navigators, either in the middle of the bar of the Mississippi, or in its immediate vicinity. Like small volcanoes of mud, the "mud-lumps" generally appear under the form of isolated cones, allowing a rill of dirty water to escape from their summits. Some of them are irregular on their surface, on which lateral orifices here and there show themselves, some in full activity, others abandoned by the springs which formerly gushed from them. The water of some "mud-lumps" is loaded with oxide of iron or carbonate of lime, which, with the agglutinated sands, form hard masses, having the consistence of perfect rocks. These hillocks vary both in their height and shape. The greater part remain hidden at the bottom of the water, and even their

summits do not reach the level of the river or sea; others hardly raise their heads above the waves; the most considerable, however, rise to a height of 6, 9, or even 19 feet, and their base covers an area of several acres. M. Thomassy is of opinion that the mouths of the Mississippi probably owe to one of these hillocks the name of *Cabo de Lodo* (Mud-Cape) which was given to them by the Spanish pilot, Enriques Barroto.

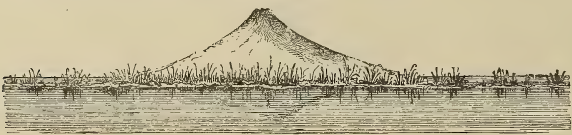
It is evident that the "mud-lumps" were not formed by the alluvium of the river, as several geologists at first supposed. The great elevation of some of the mud-hillocks above the flood-waters and tides suffices to render this hypothesis inadmissible. The sudden way in which most of these water-volcanoes make their appearance, the anchors of vessels, and the remains of cargoes, which have been found on their surface, their conical form, their terminal craters, and all the springs, "which seem to spout out as if from a subterranean sieve," indicate, on the contrary, the existence of a subterranean force always at work to upheave this bank of hillocks. Messrs. Humphreys and Abbot think that this power consists in the discharge of hydrogen gas proceeding from the alluvium of the Mississippi. According to these engineers, great masses of vegetable products—trunks of trees, branches, leaves, and seeds—brought down by the waters of the river, drift upon the bar; these are afterwards covered up, and as it were, imprisoned under a bed of mud, and, fermenting, produce gases which ultimately distend their covering, and, puffing it up into a multitude of cones, escape into the air, after having pierced the soil which held them captive.

Fig. 98.—Mud-island in course of formation.



This hypothesis sufficiently explains the upheaval of the soil and the existence of the inflammable gases which are occasionally discharged from the craters of the "mud-lumps;" but it leaves unexplained why the mud poured from the sides of the craters is transformed into a hard and compact clay, devoid of vegetable matter. M. Thomassy is of opinion that the hillocks of these bars are the orifices of regular artesian wells naturally formed by a sheet of subterranean water descending from the plateaux of the interior and flowing below the Mississippi and the clayey levels of Louisiana. However this may be, the mode in which these mud-hillocks are formed is well enough known to render it easy to clear them away from the mouths of the Mississippi and to protect the interests of navigation. When a cone of clay makes its appearance on the bar, a charge of powder is introduced into it and explodes it. Thus in the year 1858 the south-west passage was cleared of a "mud-lump" which formed a considerable island; a single charge was sufficient to sweep the whole away. The island suddenly sank; in its place a wide depression was formed, the circumference of which resembled that of a volcanic crater; at the same time an enormous quantity of hydrogen gas was discharged into the atmosphere.

Fig. 99.—"Mud-lump," with bubbling Springs at its Summit (South-west Passage of the Mississippi).



CHAPTER XLIII.

SYSTEM OF SUBTERRANEAN STREAMS.—JOINTS AND FISSURES OF ROCKS.—STALACTITES.—THE INHABITANTS OF CAVES.—THE MAMMOTH CAVE.—CAVERNS OF CARNIOLA AND ISTRIA.

ABOVE the springs, the course of subterranean rivulets is generally indicated by a series of chasms, or natural wells, which disclose the stream beneath. The arches of caves not being always strong enough to support the weight of the superincumbent masses, they necessarily fall in some places, leaving above them other spaces into which the upper beds successively sink. The *débris* of the ruin is afterwards cleared away by the water, or dissolved, atom by atom, by the carbonic acid contained in the stream, and, gradually, all the loose rubbish is carried away. In this manner, above the subterranean rivulets, a kind of well is formed, which is designated in various countries by very different names. They are called *sinks* in the United States; *dolinas* in Carinthia; *catavothras* in Greece; *pots, entonnoirs,* and *creux* in the Jura; *embues, embucs, goules, gouilles, gourgs, gourges, bêtoirs, boit tout, anselmoirs, emposieu, avens, scialets, ragagés, garagaï* in Southern France; swallow-holes, sand-pipes, sand-galls, &c., in England.

By means of these natural gulfs, it is possible to reach the subterranean streams and to give some account of their system, which is exactly like that of rivulets and rivers flowing in the open air. These streams also have their cascades, their windings, and their islands; they also erode or cover with alluvium the rocks which compose their bed, and they are subject to all the fluctuations of high and low water. The only important difference which superficial waters and subterranean currents present in their phenomena, is that these streams in some places fill the whole section of the cave, and are thus kept back by the upper sides, which compress the liquid mass. In fact, the spaces hollowed out by the waters in the interior of the earth are only in a few places formed into regular avenues which might be compared to our railway tunnels. Throughout its thickness, the rock opposes an unequal resistance to the action of the water, on account of the diversity of its fissures, its strata, and its particles. When the faults are numerous and the strata not very compact, the current gradually hollows out vast cavities, the ceilings of which fall in, and are carried away by the water almost in single grains. Where beds of hard stone oppose the flow of the rivulet, all it has done during the course of centuries has been to hew out one narrow aperture. This succession of widenings and contractions, similar to those of the valleys on the surface, forms a series of chambers, separated one from the

other by partitions of rock. The water spreads widely in large cavities, then, contracting its stream, rushes through each defile as if through a sluice.

When the water, impelled by force of gravitation, seeks a new bed in the cavernous depths of the earth, and disappears from its former channels, these are at first much easier of access than they formerly were; but, ere long, in most caves, a new agent intervenes, which seeks to contract or even completely obstruct them. This agent is the snow-water, or rain, which percolates, drop by drop, through the enormous filter of the upper strata. In passing through the calcareous mass, each one of these drops dissolves a certain quantity of carbonate of lime, which is afterwards set free on the arch or the sides of the cave. When the drop of water falls, it leaves attached to the stone a small ring of a whitish substance; this is the commencement of a stalactite. Another drop trickles down, and, trembling on this ring, lengthens it slightly by adding to its edges a thin circular deposit of lime, and then falls. Thus, drop succeeds drop in an infinite series, each depositing the particles of lime which it contains, and forming ultimately a number of frail tubes, round which the calcareous deposit slowly accumulates. But the water which drops from the stalactites has not yet lost all the lime which it held in solution; it still retains sufficient to enable it to elevate the stalagmites and all the mammillated concretions which roughen or cover the floor of the grotto.

When the action of the water is not disturbed, the needles and other deposits of the calcareous sediment continue to increase with considerable regularity. In some cases, each new layer which is added to the concretions may be studied as a kind of time-measurer, indicating the date when the running water abandoned the cave. At length, however, the soft concentric layers disappear, and are replaced by forms of a more or less crystalline character; for in every case where solid particles exist, subject to constant conditions of imbibition by water, crystals are readily produced. Sooner or later, the stalactites, increasing gradually in a downward direction, meet and unite with the needles rising from the surface of the ground, and, forming by their number a kind of barrier, obstruct the narrower passages and close up the defiles, separating the cavern into distinct chambers. Any objects which lie on the surface of the ground in these dripping caves gradually become hidden by the calcareous concretion which thickens round them. Generally speaking, when geologists find in these grottoes the remains of men or animals—the former inhabitants of the mountain caves—they are covered with a crust of stone, slowly deposited by the dripping water. In 1816, in one of the caves of Adelsberg, a skeleton, probably that of some bewildered visitor, was discovered, which the stone had already enveloped in a white shroud; but these bones have now for some years been firmly fixed in the thickness of the rock, added to, as it constantly is, by fresh layers; indeed, the lateral cave itself will soon be filled up by stalactites, and will cease to exist. In like manner, the skeletons of three hundred Cretans, who were smoked to death by the Turks in 1822, in the cave of Melidhoni, are gradually disappearing under the incrustation of stone which has enveloped them with its calcareous layers.

In the gloom of these dark recesses there is still some little manifestation of life. Since, however, plants of a higher order are unable to dispense with light, fungi form the only vegetation which we meet with, and even these growths of darkness do not always arrive at their full development; they often present monstrous and anomalous forms, which puzzle the botanist and hinder his attempts at classifying them. Some fungi never reach any further development than a mass of confusedly

organized cells; others grow so as to cover a considerable surface. The fauna, being more independent of light than the flora, reckons a much larger amount of representatives in these caves. Not only do these subterranean cavities serve as places of refuge for various birds, and as dens for several kinds of beasts of prey, such as foxes, badgers, hyænas, which carry thither the prey which they have caught (as our ancestors the troglodytes once did), but they are also inhabited by several families of animals which only exceptionally or through accident ever emerge from the depths of the caverns. Among the latter there is at least one mammal, a species of bat, which is found in the caves of Istria, the Apennines, and the Algerian mountains. The subterranean pools and streams of Central Europe also contain several varieties of a strange reptile—the *Hypochthon*, or *Proteus*—the eyes of which, being useless in the darkness, are almost aborted. Insects are the class which is best represented in these subterranean regions; but none present those vivid colours which the light of the sun conveys to most of their congeners.

Fig. 100.—Chasms of Carniola.

All are clad in a dull garb which blends with the dark shades of the rock. The most curious of these insects is a species of fly (*Phora maculata*) which never uses its wings, and various *Coleoptera* (*Anophthalmus*), in which the eyes are entirely wanting. Then follow spiders, centipedes, crustaceans, and molluscs. M. Schiner, who has made a special study of the fauna of caves, enumerates twenty-three species of animals which inhabit the caverns in the vicinity of Trieste alone; but these species form, doubtless, but a very small proportion of the subterranean tribes which live in the caves scattered far and wide over the whole earth. It is said that the caves in Kentucky contain a species of blind crayfish; also whitish rats, of a very large size; lizards, wandering gloomily in this world of darkness; and, lastly, a species of yellow cricket, which crawls like a frog, guiding its course by means of enormous antennæ.

One of these Kentucky caves, called the "Mammoth Cave," is the largest which is at present known. The whole of its extent has not been as yet fully explored, for it may be almost called a subterranean world, having a system of

lakes and rivers, and a network of galleries and passages without number, which cross and recross one another, going down to an immense depth. From the chief entrance to the further recesses of the cave, the distance is reckoned to be not less than $9\frac{1}{4}$ miles, and the whole length of the two hundred alleys that have been traced out in this enormous labyrinth is 217 miles in extent. This "Mammoth Cave" once served as a retreat for savage tribes; for skeletons of men of an unknown race have been found buried in it under layers of stalactite.

The district which is the most remarkable amongst all the calcareous countries of Europe for its caves, its subterranean streams, and its abysses, is unquestionably the region of the Carniolan and Istrian Alps, which extends to the east of the Adriatic, between Laibach and Fiume. The whole surface of the country, as in certain plateaux of the Jura in France, is everywhere pierced with deep boat-shaped cavities, at the bottom of which the water forms a kind of whirlpool, like the water flowing out of the hold of a stranded ship. Many mountains are penetrated in every direction with caverns and passages, just as if the whole rocky mass was nothing more than an accumulation of cells. On one steep cliff-side may be noticed all kinds of perforations at different heights—arched portals, and orifices of fantastic shape; on another, there are numbers of springs of blue water

Fig. 101.—Grotto of Lueg, Illyria.

gushing from the caves, or from the rocks heaped up at the foot of the cliff, and forming rivulets which disappear a little further on in the fissures of the ground, as if through the holes of a sieve. The whole surface of the plateaux, whether bare or covered with forests, is scattered over with wells, or funnel-shaped holes communicating with subterranean reservoirs. The geography of the underground labyrinth of the Illyrian caves is as yet only sketched out; and yet a considerable number of *savants*, at the head of whom stands M. Schmidl, have devoted many years of their lives to this study. Thanks to their investigations, some of the passages in these caverns, especially those of Lueg, are almost as well known as the corridors and chambers of a palace.

One of the Istrian rivers, the subterranean course of which, although still unknown as regards a great number of points, has given rise to a most continuous course of investigations, is the celebrated Timavus (Timavo), which falls into the sea near Duino, about twelve miles to the north of Trieste. Virgil's description—

"Fontem superare Timavi:
Unde per ora novem vasto cum murmure montis
It mare proruptum, et pelago premit arva sonanti"—

no longer applies to the mouths of the Timavo; at present they do not reach the

number of nine, because either the extermination of the woods of the Carso has diminished the mass of the water, or the action of the stream and the alluvium of the delta have modified the form of the shore. But still it is a magnificent spectacle to see the outlet of the three principal torrents of water, which rush foaming out of the heart of the rocks, and are navigable from their mouths to their very source. A river of this importance must certainly receive the drainage of a vast basin, and yet all the neighbouring valleys seem perfectly devoid of rivulets, and their surface presents little else but the bare rock; in fact the whole of the rain and snow-water runs away through underground caverns. We do not

Fig. 102.—Grotto of Adelsberg.

meet with any tributary until we reach a spot 21 miles south-east of the mouth of the Timavo. This tributary, known under the name of the Recca, is lost in the rock under a high arch on which stands the village of Sant-Canzian; it appears again at the foot of two precipices, and then engulfs itself in the depths of the rocks by a series of beautiful cascades, beyond which explorers have not traced it. Further on, the course of the subterranean torrent is only indicated by abysses opening here and there in the midst of the plain. In 1841, M. Lindner, who was seeking in every direction for springs of water to supply the city of Trieste, the inhabitants of which were threatened with drought, formed the idea of sending

some miners down into the chasm of Trebich, situated about four miles to the north-east of the city. After eleven months of labour the miners at last reached the floor of the lower cave, 1,062 feet below the surface of the plateau, and there in fact they found the Recca of Sant-Canzian flowing at their feet. The descent into this cave is by means of ladders, and it is thus rendered accessible by the work of man.

The most remarkable network of caverns in this region of the Alps, is that which spreads out from the south-west to the north-east across the Adelsberg group of mountains between Fiume and Laibach. The principal cave is especially curious on account of its size, the variety of its calcareous concretions, and the torrent which runs roaring through it; certainly its vast compartments, its innumerable white and rose-coloured pendants, its abysses wrapt in shade, and the eternal echo of its rushing water, would produce upon visitors a much more striking effect if its proprietors had not conceived the untoward idea of decorating their property with rustic or Chinese bridges, elegant staircases, and pyramids adorned with sentimental inscriptions.

North of the town of Adelsberg, the traveller passes along the base of a hill with steep and bare sides, bringing into view the sharp edges of its highly-pitched calcareous beds. On the right, the stream of the Poik winds peaceably in the valley; and then, its course being arrested by a headland, turning suddenly, it flows into the interior of the mountain through a kind of high portal, opening between two parallel beds of rocks. Unless the water in the stream is very low, it is impossible to follow it over the accumulation of rocks upon its bed; but on the right, at a height of a few yards, there is another entry, through which the traveller may descend dry-shod into a vast cavity or chamber, where the Poik again appears issuing from its narrow passage of rocks. At this point, the cave divides; on the north the stream, the depth of which varies, according to the season, from a few inches to 30 or 33 feet, buries itself in a winding avenue, which has been traversed in a boat as far as a point 1,027 yards from the entrance; on the north-east, a higher avenue, discovered only in 1818, pushes its way far into the heart of the mountain, branching out in various directions into narrow passages and wide compartments. This portion of the grotto, which appears to have been the former bed of the Poik, is the most curious part of the Adelsberg labyrinth; it affords wonderful groups of stalactites, especially in the Salle du Calvaire, the vaulted roof of which, having the enormous span of 210 yards, has dropped upon a hillock of *débris* a perfect forest of stalagmitic columns and white needles. The full length of the principal cave is not less than 2,575 yards; but very probably some other and still longer avenues may yet be discovered.

Although it is impossible to go in a boat along the subterranean portion of the Poik for a greater distance than 1,027 yards, by traversing the surface of the calcareous plateau we can at all events trace out the subterranean stream by means of the funnel-shaped holes which open above its course. One of these gulfs, the Piuka-Jama, is situated about a mile and a half to the north of the entrance of the Adelsberg caves; the only way to descend into this is by clinging to the branches of the shrubs and sliding down by the assistance of a cord fastened to the top of the rocks. By these means the entrance to a kind of air-hole may be reached, from which the Poik is visible foaming over its bed of rocks, and only a slope of *débris* is to be descended to reach the edge of the stream. It can only be followed in the down-stream direction for about 275 yards; but it can easily be ascended for a distance of 495 yards by passing under a high portal with lofty pillars, and in this

way a point can be reached which is less than a mile from the place where the stream disappeared in the cave of Adelsberg.

Further down the stream, the Poik is not visible again until it emerges from the mountain, where it is known under the name of the Planina; it rushes out through a circular arch at the base of a perpendicular bluff crowned with fir-trees. It really is the Poik, as is proved by the equal temperature of water and the sudden

Fig. 103.—Grotto of Planina.

increase of its liquid mass after a storm has burst at Adelsberg; but the stream always issues from the cave much more considerable in bulk than it is when it enters, owing to the tributaries which pour into it on both sides during its subterranean course of five to six miles. One of these rivulets, which comes down from the plateaux of Kaltenfeld, joins the Poik at a little distance from its outlet. Above the confluence, the principal stream can be ascended in a boat to a distance

of more than 3,500 yards, which, with the other explored parts of the subterranean river, makes about three miles. Below the point of outlet, the stream is partially lost in the fissures of its bed, and then joining the Unz, goes on and empties itself into the Danubian Save.

About a dozen miles to the south-east of the Adelsberg and Planina caves extends a large plain surrounded on all sides by high calcareous cliffs, at the base of which nestle seven villages. In this hollow, the most elevated portion of which is under cultivation, the remainder being covered with rushes and other marsh plants, there are to be found more than four hundred funnel-shaped holes resembling those in other parts of Carniola. These *dolinas,* the average depth of which is from 40 to 60 feet, have each their special name, such as the *Grand Crible* (great sieve,) the *Crible-à-froment* (corn sieve,) the *Tambour* (drum,) the *Cuve* (tub,) the *Tonneau* (cask,) pointing out the form or some peculiarity of each abyss. During extremely dry seasons, there is only one of these cavities which contains any water; but after continuous and heavy rain, the water of a stream which is swallowed up in the rocks a little above the plain, rises with a roaring noise in each of these wells. Torrents escaping from all these open *cribles* form in the wide space hemmed in by the cliffs a sea of blue and transparent water. This is the lake of Jessero or Zirknitz, the *lacus Lugens* of the Romans. The surface of the sheet of water extends over an area of 14,826 acres; at the time of great inundations this extraordinary temporary lake, thus vomited out by the underground river, is not less than 24,711 acres. The water runs away through a subterranean channel, and, farther on, empties itself into the Unz, below the Planina.

Lacustrine basins of this sort, first emitted and then again absorbed by a subterranean watercourse, are rather rare; there are, however, some other remarkable instances of them in Europe. Thus, in the eastern Hartz, in the midst of a beautiful spot surrounded by fir-trees, the charming lake called Bauerngraben (Peasants' Ditch) or sometimes Hungersee (Lake of Famine) sometimes makes its appearance; but when this mass of blue water has filled but for a few days its basin of gypsum rock, it is suddenly swallowed up, and flows away by subterranean channels into the stream of the Helme. The celebrated lake of Copaïs, in Beotia, may likewise be compared to the Zirknitz lake, at least as regards certain portions of its basin. Several of the Combes of the French Jura in the department of Ain present analogous phenomena.

CHAPTER XLIV.

RIVERS.—VARIOUS DENOMINATIONS OF WATERCOURSES.—DETERMINATION OF THE PRINCIPAL BRANCH AMONG THE AFFLUENTS OF A RIVER.—RIVER BASINS AND WATERSHEDS.—FORKS OF CERTAIN RIVERS.

GEOGRAPHERS have long discussed, and are still discussing, the precise import of the names which are used to designate running waters. How are we to lay down any distinction between a river and a stream, or between a stream and a rivulet? Obviously, no absolute difference can exist, as all watercourses are alike composed of liquid masses impelled by their own weight over an inclined bed. The only relative difference, which at first sight it seems easy to establish, consists in the greater or less quantity of water which each bed contains; but even this mode of estimation must vary in every continent and in every country, according to the importance of its hydrographical system. Many an European river would seem nothing but a slender rivulet, and would scarcely be thought worthy of a name, if it were situated in the immense basin of the Amazon. Added to this, the mass of water alters its bulk according to the various seasons. Many rivers in tropical regions, which flow very abundantly during the rains, are during the dry season often entirely dried up, or changed into a series of pools.

The term "torrent" has certainly acquired a definite meaning in current speech, in which it is commonly applied to rapid streams flowing from the mountain-side. But its very etymology shows that it had formerly the same meaning as the Arabic *wad*, and the Indian *nallah*, an intermittent river dried up during the hot season.

The principal difficulty which systematical geographers meet with is that of determining, as regards each basin, which is the chief branch; that is, which is to be considered the river *par excellence*, all the other watercourses being mere tributaries. In some cases, certainly, it may readily be perceived to which artery of the river basin the pre-eminence unquestionably belongs; but more generally it is difficult, or even impossible, to pronounce with any certainty on this question. Is it the Seine or the Yonne, the Adour or the Gave-de-Pau, the Rhine or the Aar, the Inn or the Danube, the Mississippi or the Missouri, the Marañon or the Apurimac (Ucayali), which has the best right to impose its name on the principal artery which bears onward to the sea the mingled water of the two rivers? Does the point in question chiefly depend upon length of course? If it does, the Saône and the Rhône are only tributaries of the Doubs, which has a total development, from Mont-Rizoux to the Gulf of Lyons, exceeding that of the Rhône by 93 miles. In like manner, the Mississippi would thus become a tributary to the Missouri,

which has a course more than 1,615 miles longer—an excess which is equal to three times the length of the Seine. In deciding which of the upper tributaries is the principal watercourse, would it be more to the point to compare the quantities of the liquid supply which each brings to the common fund? In this case the Yonne, the Aar, and the Inn are rivers which are fed by the Seine, Rhine, and Danube respectively. Ought we not rather to consider the more or less rectilinear direction, and the comparative geological unity of the valley of each affluent, as the principal signs which should determine the real *river?* Then, the Rhône and the Seine are nothing but secondary watercourses in comparison with the Saône and the Yonne, and the Yonne itself must yield its pre-eminence to the Cure.

The *savant* who devotes himself to the thankless task of seeking out the principal branch in a river system has, therefore, to take account of the most diversified points of detail: the average mass of water, the length of the course, the general direction of the valley, and the geological nature of the soil; but, whatever may be the result of his investigations, he must ultimately yield to the all-powerful authority of tradition. For it is tradition, and not science, which has invested rivers with their titles and dignity; it is the voice of our ancestors, founded on a thousand circumstances in connection with mythology, the history of conquests or colonization, agriculture, navigation, or even on various natural phenomena, which has arbitrarily decided to give the pre-eminence to some particular watercourse over the other rivers of the same system. It is now too late to try to change the hydrographical nomenclature.

But even were it possible, this alteration would be almost entirely inefficient, for the vitality of nature will not accommodate itself to the strict classifications to which pedants would seek to restrict it. It is only by pure abstraction that we come to consider a river as an isolated existence. In reality it is the aggregate of the streams and rivulets which flow into it from all the points of its basin; it unites the millions of rills which are set free from the ice, or trickle from the crevices of the rocks; it is made up of the innumerable springs which ooze out from the ground saturated with rain or covered with snow. A river is in a constant process of change, and every tributary takes its share in this work of transformation. The entire drainage area, and not any particular affluent, ought, therefore, to be considered as the real river. We must take into account the Missouri, the Ohio, and the Red River, no less than the Mississippi, extending its long and constantly increasing peninsula of mud into the Gulf of Mexico; also the Tapajoz, the Rio-Negro, and the Madeira flowing with the Solimoes into the vast estuary of the Amazon. In like manner, to use the language of the sailors of the Bay of Biscay, the "two seas" of Garonne and Dordogne unite their waters to compose the "Sea" of Gironde.

Those names of rivers which are formed by the contraction of the designations of their chief tributaries are, indeed, the only terms which are geographically correct. We may mention, as examples, the names of the Somme-Soude, the Thames (Thame, Isis), the stream of Gyronde (Gyr, Onde) in the Upper Alps, and, better still, that of the Virginian river Mattapony (Mat, Ta, Po, Ny). The aggregate of the arteries of a river system may be compared to the branches and twigs of an immense tree. The Rhine and the Mississippi remind one of the oak, by the majesty of their shape and the magnitude of their branches, thrown out at right angles to the parent stem. The Nile, with its long trunk devoid of lower boughs, and crowned with its plume-like terminal branches, recalls to our mind the palm-tree of the oasis. These comparisons, it is true, have no scientific element in

them, but still they do not fail to present themselves to the eye, and geographers, as well as artists, must be to some extent struck by them.

Lofty mountain chains, the peaks of which tower up into the sky, crossing the very tracks of the clouds, collect in proportion a much larger share of moisture than the plains, and consequently give rise to the most abundant streams of water. Nevertheless, as low-lying countries, or those possessing a moderately elevated vertical outline, embrace an area much more extended than that of mountainous districts, these flat regions are the localities where rivulets spring from the earth in the greatest number. In a general way, the ravines or dells in the plains in which the water of river-sources is collected are representations in miniature of the deep gorges and the hollows of erosion existing in high mountains. But amongst the incipient river affluents there are some which take their rise on level plateaux, or in some trifling depression of the ground; there are others, especially in the great plains of Russia, which issue from lakes or marshes, which spread out in vast sheets in the centre of the country. Thus, the watershed, that is, a ridge separating two slopes, or perhaps a mere ideal winding line, on each side of which the water flows in an opposite direction, is developed under the most diversified conditions. A river basin, that is, the area which is traversed by all its affluents, may be bounded on one side by the jagged ridge of some mountain-chain, on the other by the gentle undulations of a range of hills, farther on by an almost imperceptible rising in some low-lying plain. In certain localities, indeed, it is necessary to level the soil in order to ascertain the exact spot where the "divorce of the waters," as the ancients used to call it, actually takes place. Added to this, even in the mountains, the ridge line, or the highest elevation, is very far from uniformly coinciding with the watershed which separates two drainage areas. Mountains exhibit such infinite variety in their original form, and the agents which denude them have hollowed out their sides in ways so diversified, that some rivers actually take their rise on the contrary side of the mountain to that which they are about to water.

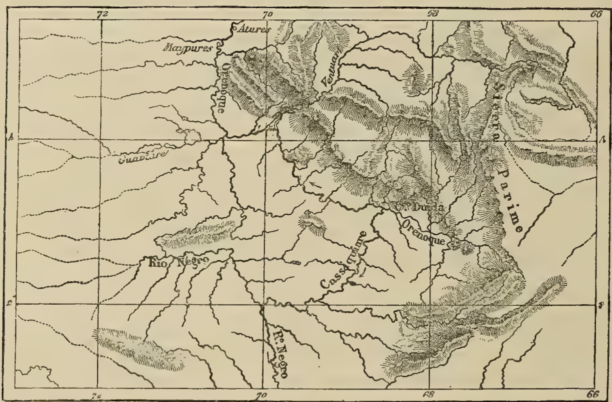
Several river-basins exhibit rather a curious phenomenon. The watershed line, traversing high mountain-chains, plateaux, and marshes, and separating two hydrographical systems, is interrupted by breaches or gaps, through which the water can flow out of one basin into another. On reaching this breach the flow of water, being attracted by two inclines, forks out into two streams running in contrary directions, and sometimes towards two different seas. Thus, in Columbia the Upper Orinoco divides into two rivers, one of which empties into the Atlantic immediately to the south of the Antilles, whilst the other, known by the name of the Cassiquiare, runs to the south-west towards the Rio Negro, a tributary of the Amazon. The river, therefore, which collects the waters of the upper basin of the Orinoco is a tributary of two seas at the same time; it assists in turning the whole of the Guianas into a great island, surrounded on one side by the ocean, on the other by a channel navigable along a double incline, having its summit level at the foot of the high mountain of Duida.

This phenomenon of bifurcation, which has been rendered famous by the journey of Humboldt and Bonpland, is also found, although certainly on a less magnificent scale, in several other countries of the earth, some mountainous, and others only slightly undulating. In some places, owing to the kind of indecision which is produced in the liquid mass by the double attraction of the two inclines, man has been enabled to regulate at his will the course of the two diverging streams, or even entirely to do away with the bifurcation by means of a dam, or

some other hydraulic works. But to make up for it, in a multiplicity of other cases human ingenuity has been able to utilize the depressions of the surface so as to draw off laterally an arm of a river, and thus create an artificial fork.

In Europe alone numerous instances may be mentioned of natural bifurcations. In Sweden a small lake, which is situated at a height of more than 3,300 feet at the foot of the lofty mountain of Sneehättan, simultaneously feeds the stream of Lougen, which descends towards Christiania, and that of Romsdal, which empties itself into the Molde-Fjord, between Bergen and Trondhjem. Added to this, the marsh of Kol, on the plateau of Hardanger, gives rise to eight rivulets, each diverging in its own particular direction. In like manner, on a rocky plateau situated at a height of about 2,640 feet to the east of Puy de Carlitte, in the Eastern Pyrenees, we find the little pool of Las Dous (the Two) emptying its waters simultaneously into an affluent of the Têt du Roussillon and into the rivulet of Angoustrine, a tributary of the Sègre and the Ebro. Central Italy affords a still more curious instance of bifurcation. It appears unquestionable that, at the time

Fig. 104.—Bifurcation of the Orinoco.

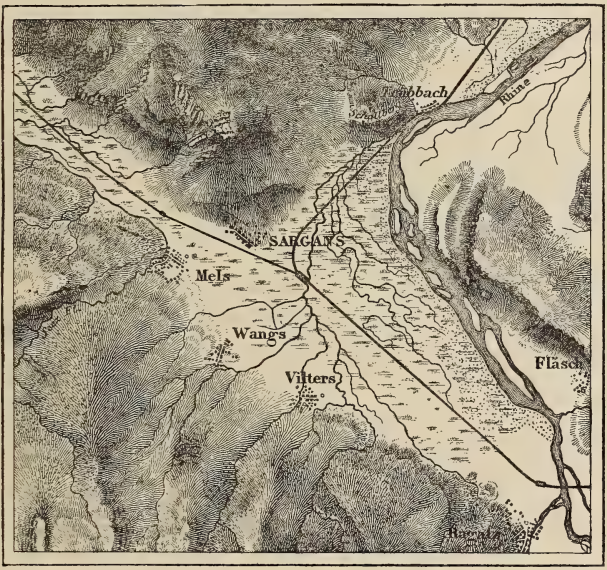


of the Romans and during the first centuries of the Middle Ages, the Arno was divided into two branches, one of which emptied itself directly into the sea, whilst the other, crossing on the south the valley of Chiana, fell into the Paglia, a tributary of the Tiber. When the River Arno, gradually sinking its northern bed, ceased to flow into the valley of Chiana, the water which descended from the lateral ravines in this almost horizontal depression flowed to a very slight extent on one side into the Tiber, and on the other into the Arno; but more often it stagnated in wretched marshes, which were a constant source of fever. These marshes have now disappeared, thanks to the splendid hydraulic works undertaken since Torricelli's time by the Tuscan engineers for the amelioration of the valley. By means of the alluvium brought by the torrents on both sides into the settling basins, an artificial watershed has been created in the middle of the valley, giving the water two very perceptible slopes, inclined in contrary directions. One of the tributaries of the basin of the Seine also once offered an instance of constant bifurcation; at Mœurs the grand Morin divides into two streams, one of which flows

down to the Marne, and the other feeds the Superbe—an affluent of the Seine. But lately, owing to the destruction of the woods, the sources have become diminished, and the double communication of the water only takes place in an artificial way by means of a dam.

Amongst phenomena of a like nature, we must also class the division of the contents of a river into two branches, which, flowing separately each in its own valley, ultimately reunite at a considerable distance below the point of bifurcation. It is not improbable that, at a recent geological period, the Rhine was thus divided into two branches, embracing in its course an immense island of rocks and mountains comprehended between the lakes of Wallenstadt, Zurich, and Constance, and the present confluence of the Aar and the Rhine. In the earth's history the

Fig. 105.—Sargans Depression.

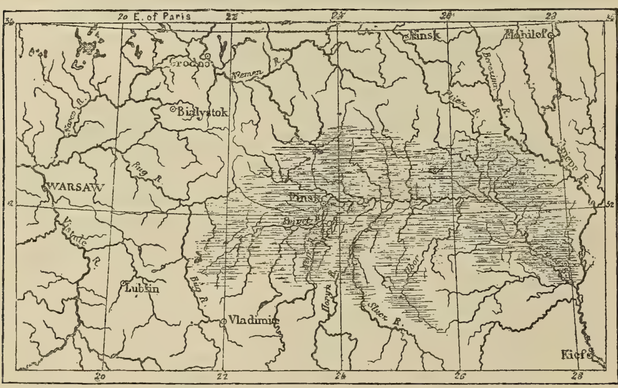


two valleys may be looked upon as having an equal title to be considered the axis of the river-basin, as they have both served as the river-bed, either simultaneously or in turn. Between Meyenfeld and Sargans, at a height of 1,580 feet, the Rhine doubles round suddenly to the north-east, and, penetrating a narrow defile, runs down to the Lake of Constance, which it crosses, and flows on to join the waters of the Aar and the Limmat at about 93 miles below Sargans. The latter town is situated on an isthmus of pebbles and peat, which divides the present bed of the Rhine from its former bed, which tends towards the north-west. If this isthmus, which is only about 16 feet high, were to disappear, the river would again divide into a fork, and one of its arms would flow on to empty itself into the Lake of Wallenstadt, and then into the Lake of Zurich and the valley of the Aar. Various hypotheses have been propounded to explain the formation of this isthmus which

has severed the river-basin into two parts, and forced the whole body of the Rhine to flow into the Lake of Constance. It is probable that this mass of pebbles is a portion of a slope of *débris* brought down by the torrent of Seez from the recesses of the gorge of Weiss-tannen (White Firs), and deposited at the outlet of the lateral valley. So long as the river was able to clear a way through these heaps of stones, a portion of it followed its old course towards the Lake of Wallenstadt; but, being constantly impeded by the ever-growing barrier, it was ultimately compelled to open out a new outlet towards the north.

A great number of examples of this double flow of portions of one mass of water towards two different basins are afforded by low and marshy plains. The marshes of Pinsk, in Volhynia, serve as a common source to various affluents both of the Vistula and the Dnieper, thus forming a link between the Baltic and Black Seas. In spring, when the snow melts, and towards the end of autumn, after the heavy rains, a series of lakes, wet marshes, and temporary rivulets connect the inland Caspian with the Sea of Azof and the Euxine. The water of the Kalaus, coming

Fig. 106.—Marshes of Pinsk.



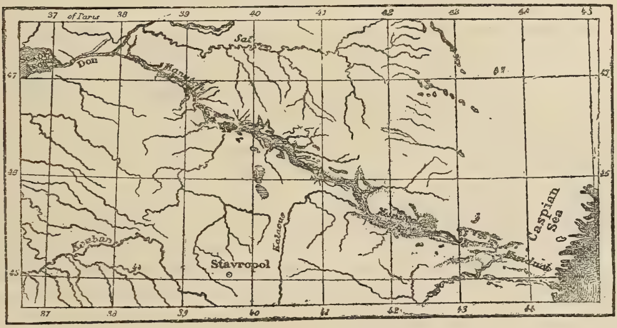
down from one of the rugged valleys of the Caucasus, divides, and forms a temporary channel between the two basins, which were, indeed, once united in one and the same ocean.

The two principal river systems of North America—those of the Mississippi and the St. Lawrence—are likewise blended together for a few days after a prolonged rainfall. Even before the construction of the canal which at present unites the two rivers, small boats could sometimes pass from the Chicago River into the Illinois, and thus cross the scarcely-indicated watershed which divides the basin of Newfoundland from that of Mexico. In a recent period—that is, about 4,500 or 5,000 years ago—the union of the two river-basins, which has now become but temporary, appears to have been of a permanent character. The calculations and observations of Sir Charles Lyell, Schoolcraft, and many American geologists, render it very probable that, at this epoch, all the upper affluents of the Mississippi and the St. Lawrence fed a lacustrine reservoir, the vast sheet of which, situated about 600 feet above the level of the ocean, stretched towards the north as far as the mouth of the Wisconsin, and on the east joined Lake Michigan, covering

all the intervening peninsulas. The centre of the continent was occupied by a sea as large as our Mediterranean, which emptied itself into the ocean by an immense delta, each arm of which was one of the greatest rivers of the earth.

The bifurcations of watercourses do not, however, all take place on the surface of the ground; and if the deeper layers could be disclosed to our view, it is probable that we should find the majority of river-basins would afford instances of subterranean derivations. In a country like France, in which geological exploration has seriously commenced, a considerable number of these curious phenomena have been

Fig. 107.—The Ponto-Caspian Isthmus.



discovered, although they are in general but little noticed. Thus, in the Basses Pyrénées, the Gave d'Ossau forms a fork at the foot of the high hill of the Sévignac. One arm, running to the north-west, flows on to join the Gave d'Aspe, and forms the Gave d'Oloron; but the other buries itself under the rocks, and reappears about five miles to the north, in two very strong springs, the stream resulting from which, called the Neez, empties itself into the Gave of the same name, not far from Pau. In like manner, in the centre of France, the Haute-Vézère sends one of its arms under the ground, for a distance of about three miles, to feed the stream of the Isle, which meanders through its deep valley in long parallel windings.

CHAPTER XLV.

THE HYDROGRAPHICAL SYSTEMS OF VARIOUS PARTS OF THE WORLD.

A STUDY of the map with regard to the distribution of rivers over the surface of the earth, brings before our view, at a glance, this fact—that the watercourses which are tributaries of the Atlantic exceed considerably, both in number and importance, those which belong to the great Pacific Ocean. This sea, the greatest of all seas, receives directly only five considerable rivers—the Me-Khong, the Yantse-kiang, the Hoang-ho, the Amur, and the Columbia; but the comparatively narrow channel of the Atlantic is the reservoir into which the most enormous rivers of the earth pour their contents—the Uruguay and the Parana, the River of the Amazons, the Orinoco, the Mississippi, and the St. Lawrence, without reckoning the Congo, Niger, and Gambia, all the watercourses of Western Europe, and, by the intervention of the Mediterranean, the Nile and the Danube—the two great rivers of the ancients. This unequal distribution of rivers is a result of the semi-circular arrangement of the Andes, the Californian Mountains, and those of Kamchatka and Siberia, all round the basin of the Pacific. The western side of South America is excessively poor in rivers. All over this narrow belt, which is on the average not one-tenth as wide as the opposite Atlantic side, and is, besides, rarely visited with rain, there are at most but two or three rivers which are navigable. The streams of Chili and Western Columbia would scarcely merit the name of rivulets in the basin of the gigantic Marañon.

In a hydrographical point of view, the continent of Asia may be divided into three entirely distinct systems—those of the north, the centre, and the south. The first is the great plain of Siberia, which is gently inclined towards the Frozen Ocean, and the whole extent of which is crossed by three parallel rivers, certainly among the largest, but also, perhaps, the least used by man, of all the watercourses in the world. In the centre of the continent there are several closed basins, consisting of plateaux more or less desert, the streams of which are lost in some lake, or evaporate during their course. The southern and eastern countries of Asia are the portions of the continent which show a genuine vitality—thanks to the sea which bathes them, the deeply indented shape of their peninsulas, the varied productions of their soil, and, above all, to the numerous watercourses which traverse them.

The most remarkable of these rivers are arranged in pairs, so as to constitute three groups of twin currents. These are the Tigris and Euphrates, the Ganges and Brahmaputra, the Yantse-kiang and Hoang-ho. In each of these pairs, the

two rivers take their rise side by side in the bosom of the same system of mountains, and, bending their course in opposite directions, each describes a vast semicircular line all across the continent, and ultimately again unite before they empty themselves into the sea through the same delta, or at least through neighbouring mouths. There is another point which still further augments the analogy between these double fluviatile arteries, viz., that each empties its waters into one of the three seas situated to the east of the three southern peninsulas of Asia. The Shat-el-Arab flows into the Persian Gulf, to the east of Arabia; the Ganges into the Bay of Bengal, to the east of India; the Chinese rivers into the Pacific Ocean, which stretches to the north and east of the Indo-Chinese peninsula.

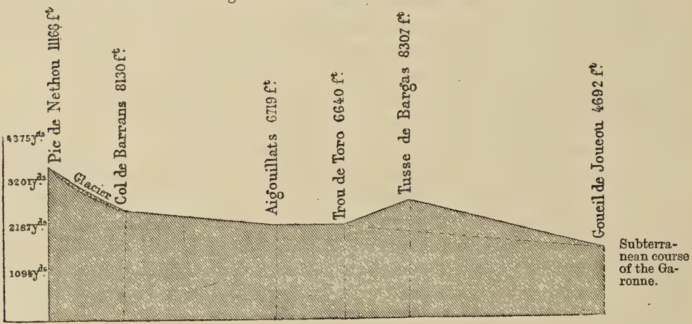
But the most remarkable phenomenon of this class is that presented in East Tibet by the parallel valleys of all the streams rising on the Kachi plateau, and thence diverging towards the continental coast-line. Between the Irrawaddi and Yangtse deltas there is a shore distance of no less than 5,500 miles, and between these two rivers flow the Lutzé-kiang (Salwen), and the Lantzan-kiang (Mekong), the two great watercourses of Further India. For a space of several degrees of longitude, all these river valleys are in such close proximity that on ordinary maps their channels seem to become intermingled.

In order to understand the general features of the river system of the Asiatic continent, there is a fourth group of allied rivers which we must also notice—the Indus-Sutlej. Certainly these two rivers of the western regions of Hindustan unite their waters at a rather considerable distance from their mouth; but their lower course has entirely the character of a delta. The Indus and the Sutlej were probably once separated, and became united in consequence of the alteration of their course, and the considerable elongation of the delta common to both which received their alluvium. In like manner, at the time of Alexander the Great, the mouths of the Tigris and Euphrates were situated at a good day's march from each other; but at the present day the two river-arms coalesce at some considerable distance from the sea, and form together the Shat-el-Arab. The Indus and the Sutlej may, therefore, be classed among the double rivers, as their sources lie very close to one another; their courses take an entirely different direction, and they also have a common outlet. As the waters of this fourth group of rivers descend from the same mountain range which gives rise to the Ganges and the Brahmaputra, we might even say that in the north of Hindustan there is a double system of allied rivers which at their sources are almost joined. The four most considerable currents of water in India, taking their departure from nearly the same point, flow away in opposite directions, and, after describing enormous circuits, unite in pairs, as if to obey some double law of harmony and contrast—the Indus and the Sutlej to the east, the Ganges and the Brahmaputra to the west. They are the four animals of the Indian legend—the elephant, the stag, the cow, and the tiger—which spring down from the same mountain peak into the green plains of Hindustan.

The contrast offered by Europe proper—so rich in mountains, peninsulas, and deep indentations of the coast—to the vast plain of an almost Asiatic character which distinguishes Eastern Europe, shows itself equally in the river systems of the two halves of the continent. In Western Europe the Alps and the other chains of mountains radiating from them determine the characteristics of the water system. In the Slavonic countries, inhabited as they are by peoples hardly emerged from barbarism, the great rivers, such as the Volga, the southern Dwina, the Niemen, the Bug, and the Dnieper, all take their rise in the marshy or slightly

undulating regions which occupy the interior of Russia. Certainly they roll down a very considerable mass of water; but in their historical importance they are very inferior to the rivers which spring from the Alps, and, flowing in every direction, water the various countries of Western Europe—the principal theatre of modern civilisation. The Alpine group of streams is that to which it is chiefly material to devote a separate study. From the sides of the St. Gothard, the centre of the Alps, three rivers, not counting the Reuss, take their rise—the Rhine, the Rhone, and the Ticino—falling respectively into the North Sea, the Mediterranean, and the Gulf of Venice. Two other watercourses, which do not precisely descend from the St. Gothard itself, take their rise in its vicinity. These are the Aar, the principal tributary of the Rhine, and the Inn, a stream more important than the Danube—the name which it assumes below the point of their confluence. Here, then, are five rivers which radiate towards four seas from one single group of the Alps, but as isolated rivers, and not in the form of double systems, like those of India and China. However, these distinct watercourses, especially the Rhone and the Rhine, present some remarkable peculiarities. These two great rivers, nearly

Fig. 108.—Sources of the Garonne.



equal in volume, flow each in a diametrically opposite direction; then, turning suddenly towards the north by an abrupt bend, and crossing a lake of considerable dimensions—one the Lake of Geneva, the other the Lake of Constance—cross the parallel chains of the Jura either in rapids or cataracts, and, finally emerging from the mountainous regions, flow, the one directly to the north, towards the German Ocean, the other directly to the south, towards the Mediterranean.

Other groups of the same mountain chain, such as those of the Viso and the Levanna, near Mont Cenis, form secondary centres for the radiation of streams; but as regards their hydrographical importance, none of them can be compared to the central group of the St. Gothard.

The great rivers of peninsular Europe, which are not fed by the Alpine snows, flow to the north of the almost continuous line of mountains which is formed across the continent by the chains of the Pyrenees, the Cevennes, the Jura, the Alps, and the Carpathians. The rivers which descend to the south are smaller, on account of the more contracted area which is afforded them in Europe by the Mediterranean slope. But it must be remarked that the line of summits does not exactly mark out the watershed where the waters divide, some flowing to the north, the others to

the south; there is, in fact, a complete mutual invasion of the opposite basins, and their respective interpenetrations fit, as it were, one into the other. A river flowing to the north receives affluents from the southern side of the mountains, and another flowing to the south receives those from the north. Thus, on the Tatra (Carpathians) the watershed is far from coinciding with the line of summits, and cuts across the chain of mountains. The Arva, coming from the north, penetrates the mountain chain, and flows on into the Theiss; whilst the Poprat, taking its rise in the south, hollows out a bed for itself through the gorges, and runs on to join the Vistula. In like manner, the Garonne rises in the glaciers of the Maladetta, to the south of the principal chain of the Pyrenees, and makes its way into the district of Aran and the plains of France; but to effect this it is compelled to cross the base of the mountain group of Poumero through a subterranean gulf 4,376 yards long. The water, which disappears on the Spanish side in the high valley of Essera, reappears on the other slope of the mountain at a point 1,980 feet lower down. The rising spring, the water of which thus pierces right through the rocks of Poumero, was once held sacred; it is called the "Goueil de Joueou" (Jupiter's eye).

In North America the same radiation of rivers exists as in Europe, but it spreads round three centres, two of which are mountain groups, and the other a merely gradual and imperceptible rising of the plain. In the territory of Idaho, between the 43rd and 44th degree of north latitude, a great peak towers up to a height of 13,779 feet, to which Lieutenant Reynolds has given the name of "Union Peak," because the water from its melted snows, being soon increased and converted into important rivers, flows towards the Colorado on the south, the Missouri on the north, and the Columbia on the west. More to the south, but still in the angle formed by the valley of the Colorado and those of the tributaries of the Missouri, the Rio Grande del Norte takes its rise, thus completing the system of radiation of large rivers round an elevated group of the Rocky Mountains. Nine degrees farther north, in the vicinity of Murchison Peak, several of the more important springs rise which feed the Fraser River, the Columbia, the Saskatchewan, the Athapasca, and the Mackenzie. According to Antisell, three of these rivers are fed by the snow of the same mountain. The sources of the Mackenzie and the Columbia take their rise at a distance of about 200 yards from each other; and in fourteen paces or so a man may walk from the origin of the Columbia to that of the Saskatchewan. These, then, are the spots whence the radiation takes place of the great rivers on the north-west of the continent. The radiating centre of the rivers of the plain is situated a little to the west of Lake Superior, in the vicinity of the Red Lake, Lake Itasca, Lake of the Woods, and several sheets of fresh water which are scattered over the highest part of the lower plateaux of North America. Thence spring forth the sources of the Mississippi proper, those of the St. Lawrence, and the Northern Red River, a tributary of the great Lake Winnipeg, which communicates with the Mackenzie River and the Frozen Ocean by a series of sheets of water. The radiating centre of the river system of the plains serves to link together the two centres of the Rocky Mountain chain. It forms the complement of them.

South America is *par excellence* the country of rivers. There roll down the immense Amazon, navigable for more than 3,000 miles; the mighty Parana, signifying by its name "The River" pre-eminently; and the Orinoco, surnamed "the Father of Waters," the drainage area of which is not one-third so extensive as that of the Mississippi, although the latter river pours down a much less considerable body of water. On account of the narrowness of the Pacific slope, all

the great watercourses of South America flow over the plains situated to the east of the continent; but they do not all take their rise in the chain of the Cordilleras. The Orinoco takes its rise in the mountains of Guiana, the Marañon in the Andes, the Parana and the greater part of its tributaries spring from the high plateaux in the interior of Brazil. These rivers, therefore, do not radiate round the same centre; on the contrary, they belong to two basins which are perfectly distinct, and, indeed, cross one another at right angles. The basin of the Amazon tends, in fact, from west to east, whilst the plateaux and plains in the middle of the continent, forming a basin in the direction of the meridian transversal to that of the Amazon, are watered on the north by the Orinoco and the Rio Negro, on the south by the Tapajoz, the Madeira, the Paraguay, and the Parana. The distinguishing feature of the river system of South America is in the fact that the three principal rivers are interwoven by means of an almost continuous line of running water, which extends from north to south—from the mouth of the Dragon to the estuary of the Plata. More than half a century ago Humboldt placed the matter beyond all doubt

Fig. 109.—Interlacing Basins of the Amazon and the La Plata.

that the Cassiquiare empties its water both into the Orinoco and into the Rio Negro. The communications between the Tapajoz and the Paraguay are not so perfect, but they nevertheless exist in several places. According to M. de Castelnau, the proprietor of the Estivado farm irrigates his garden by turning the water from an affluent of the Paraguay into the bed of the Tapajoz, and makes the little channels flow at his will towards either the northern or southern side of the continent. In like manner, there is a stream near Macu which at the time of inundations is divided into two currents, one forming a part of the Plata system, and the other belonging to that of the Amazon. Farther to the east, the Rio Guaporé, an affluent of the Madeira, and the Jauru, a tributary of the Paraguay, take their rise in a plain which is periodically inundated during the rainy season. At the foot of the Bolivian Andes a similar intermingling of basins takes place, as regards the Marmore and the Pilcomayo. Thus, the Caribbean Sea and the mouth of the Orinoco are connected with the estuary of the Plata by a continuous series of rivers, streams, and marshes.

The numerous watercourses which proceed from the central plateaux of the continent are all disposed parallel to the Tapajoz and the Madeira. The chief affluents of the Orinoco, on the contrary, follow the same direction as the River of the Amazons. We are, therefore, correct in saying that the river system of South America comprehends two basins crossing one another. The Rio Magdalena, the Atrato, and the other streams of Guiana, are all rivers with distinctly limited basins; but it must be remarked that they all flow from the south to the north, in the same direction as the southern tributaries of the Amazon.

In that portion of the earth which is the most massive and the least articulated in its shape an harmonious correspondence is found between the watercourses and the continent itself. As long as the greatest part of Africa was an unknown region, geographers were able to attribute to its rivers all kinds of imaginary courses; they could, as their fancy dictated, make the Nile, the Niger, and the Congo take their rise from one common source, or interweave in a complete network all the tributaries of these great rivers. But the discoveries of modern travellers will now warrant us in forming some general idea of the African river systems. This land, so devoid as it is of peninsulas and of deep indentations in its coasts, does not, probably, present more than one centre of radiation for its waters, which centre is situated about the middle of the continent. From this point descend the Shary, the Binué—a tributary of the Niger—various streams falling into the Congo, and some important affluents of the Nile. Still, the principal branches of the large rivers take their rise at enormous distances from one another, and in the general features of their courses exhibit only some transient and slight similarities. The basin of the Nile is partly separated from that of the Niger by a great depression, the centre of which is occupied by Lake Tsad. In like manner, several lakes and their affluents are interposed between the three basins of the Nile, the Zambesi, and the Congo; lastly, a small independent inland sea—Lake N'gami—having its own special system of tributaries, fills up the space between the basins of the Zambesi, the Orange River, and the Limpopo. There is another point which distinguishes African rivers from those of other countries; this is an absence of any extent of ramifications. In this characteristic they resemble their mother-continent—a gigantic trunk without peninsular branches. From Assuan to Rosetta, a length of seven degrees, the Nile does not receive a single visible affluent; nevertheless, it must necessarily be replenished by several underground tributaries, for its liquid mass is much more considerable in Egypt than in Nubia.

Australia is even poorer in rivers than the east of the African continent itself. With the exception of the Murray, its affluent, the Darling, and a few other rivers that are navigable at all times, the greater part of the watercourses in Australia can scarcely be said to exist except during the rainy season, and in summer their beds are only indicated by pools of stagnant water at intervals. Their special characteristic appears to be periodicity.

The general features of the river systems of each part of the world may thus be shortly summed up:—

Northern Asia is distinguished by rivers of simple character. In the south and east they are allied.

Europe is distinguished by two centres from which the streams radiate—one situated in the midst of vast plains, the other in the heart of the highest mountains of the continent.

North America is characterized by a radiation of the rivers from three centres,

two of which, being elevated groups in a mountain-chain, are linked together by the third, occupying a marshy rising in the plains.

South America is characterized by the crossing of two mutually transverse basins and the continuous union of the river systems.

Africa is distinguished by the comparative independence of its watercourses and their poverty in tributaries.

Australia, by the small number of its rivers and the periodicity of their existence.

The form of each continent, and the phenomena of climate peculiar to them, have thus determined the rise of rivers, which are modelled on a particular type in each division of the world. As all continental masses differ one from another, the circulating system of each naturally harmonises with the general features of the regions which the running waters traverse and vivify.

CHAPTER XLVI.

THE RIVER OF THE AMAZONS.—DIVERSITY IN THE CHARACTER OF WATER-COURSES.—UNITY OF THE LAW WHICH GOVERNS THEM—EQUALISATION OF THEIR SLOPES.—UPPER, MIDDLE, AND LOWER COURSES OF RIVERS.

THE river *par excellence*, the glory of our planet, is the great stream of the Amazons, which, next to the great upheaval of the chain of the Andes, forms the principal feature of the Columbian continent. This moving fresh-water sea, which takes its rise at a short distance from the Pacific, and empties itself into the Atlantic through an estuary measuring 186 miles from promontory to promontory, serves as a line of division between the two halves of South America, and, like a visible equator, separates the northern hemisphere from the southern along a length of about 3,000 miles. Everything belonging to this great central artery is on a colossal scale. In its immense basin, embracing an area of 2,700,000 square miles, it collects two or three thousand times as much water as the Seine. In different parts of its course this immense river is known under various names, as if it were composed of distinct streams set end to end, and, together with its tributaries, its *furos*, or false rivers, its *igarapés*, or lateral arms, offers scope for steam navigation of more than 30,000 miles. It is so deep that sounding lines of 150, 200, or even 300 feet have failed to measure its depths, and frigates can ascend it for more than 1,000 leagues. Its width is so great that in some places it is impossible to see the opposite bank, and at the mouths of the Madeira, the Tapajoz, the Rio Negro, and some other of its great affluents, the distant horizon closes in upon the water just as in the open sea. It is replenished by dozens of rivers which scarcely find their equals in Europe, and many of them, being yet unexplored, still belong to the realms of fable. In several places its banks serve as limits to two distinct faunas, and many species of birds will not venture to cross the broad sheet. Like the sea, it is inhabited by cetaceans; like the sea, too, it has its storms, and during a tempest the waves will rise to several feet in height. When we sail over the grey water of the estuary at the mouth of the river, we feel tempted to ask, says M. Avé-Lallemant, whether the sea itself does not owe its existence to the enormous tribute which the rolling current is incessantly bringing down to it. The difference in the motion produced by the movement of the waves or by the force of the current is the only thing which points out on which domain a voyager is sailing—that of the fresh or salt water. Even in late years, the greater part of the inhabitants of the shores of the Amazons—white, black, or red men alike—are in the habit of fancying that the great river surrounds the whole universe, and that all the nations of the earth are denizens of its banks.

Certainly, the difference is considerable between the mighty South American river and some slender stream; as, for instance, the Argens, which is crossed by a bridge with a single arch, and can readily be waded through by travellers. But whatever may be the comparative importance and the discrepancy of aspect in these rivers, they are none the less governed by the same laws. The geographer can describe them all together by forming an outline of an ideal river, the course of which would afford the combined phenomena of all the streams which traverse the globe.

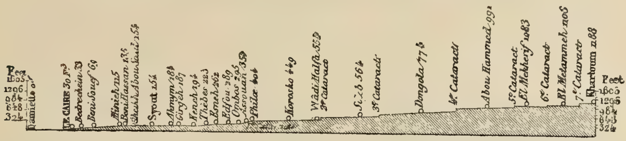
The function of rivers in the plan of nature is incessantly to renovate the surface of continents, to convey the life and the alluvium of lofty mountains down to the plains and the coasts of the ocean. It has often been said that a landscape cannot be really beautiful when it is destitute of the rippling motion of a lake, or the presence of running water. The fact is, that man, whose life is so short, and, in consequence, so restless, has an instinctive horror of immobility. To make him fully appreciate the vitality of nature, it is requisite that motion and sound should bring it home to his senses. Only by a course of long reflection can he duly estimate the long-protracted movements of the terrestrial crust; he therefore needs to view the rapid bounds of the water leaping down in cascade after cascade, or the harmonious undulations of the waves. More than this, he also demands the contrast between the stable and the unstable, between restlessness and rest. This is the cause why a field of snow as far as the eye can reach, a desert without water, a sky without clouds, or a shoreless ocean, fail to excite in him anything better than a gloomy or melancholy admiration. In the presence of these spectacles man feels himself crushed, whilst in a narrow valley, with its streams of running water, he is fully conscious of his own vitality.

On our earth water is, *par excellence*, the symbol of motion. It flows and flows on for ever, without rest, and without fatigue. The lapse of centuries cannot dry up the slender rill of water trickling from the fissure of a rock, and fails to silence its soft and clear murmur. It leaps down joyously, in cascade after cascade, to mingle with the impetuous torrent; then, blended with the calm and mighty river, it flows on, and loses itself at last in the immense and mysterious ocean—that tomb in which every water-borne fragment finds a temporary grave till the resolved elements enter again into the vast bosom of nature and reassume fresh forms of vitality. Motion is only another word for action. Water does not merely flow through a bed hollowed out ready for it; it is incessantly eating away, undermining, corroding, washing away, and moving the earth and the rocks which hem it in or oppose its course. Pebble by pebble, and grain by grain, it is carrying the mountains into the sea. Water, as Pascal says, is "not merely a road in motion, it is also a travelling continental mass which, in the centuries of yesterday, was covered with the eternal mountain snow, and will in the ages of to-morrow be fixed on the sea-shore, to augment the domain of man." Rivers carry out the circulation of solid as well as of liquid matter; they are, like the blood, ever-flowing life-renewers. It is, then, requisite that we should study carefully the mode of operation which rivers adopt in their renovating action on the continents they traverse.

Every current of water is constantly tending to equalise its slope, to increase it where it is almost imperceptible, and to diminish it where it is too rapid. The whole course of the river, from its mountain source down to its junction with the sea, may be compared to an avalanche falling from the heights of some snow-clad peak. The masses which sink down into the valleys modify gradually in their fall

the outline of the cliffs. The projections are broken down, the fissures are filled up, a gracefully curved slope of *débris* abuts against the vertical walls, and extends in a gentle incline down into the plain. Owing to all these excavations and fillings up, the passage through which the avalanche makes its way ultimately assumes an outline of considerable regularity. Although less abrupt in its progress, less violent in its effects, and gliding over a gentler slope than the avalanche, still the river adopts a very similar course of action; it clears away the obstacles before it, and

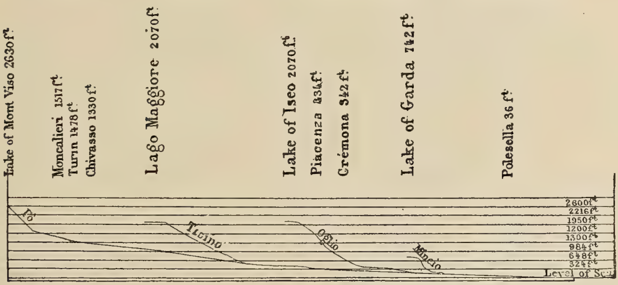
Fig. 110.—Slope of the Nile from Khartum to Damietta.



fills up any depressions, appearing as if it endeavoured to provide for itself a uniform incline down to the sea.

The portions of a river's course where this equalisation of its incline chiefly takes place are naturally those where the declivity of the bed is most rapid, and where the waters consequently attain their highest rate of speed. It may be generally asserted that those portions of the river-beds which are distinguished by the most abrupt incline are also the most elevated; for in almost all the countries of the earth the plains lie round the circumference of the land, and the mountains rise far in the interior. Most rivulets and streams take their rise thousands of feet

Fig. 111.—Slope of the Po, the Ticino, the Oglio, and the Mincio.



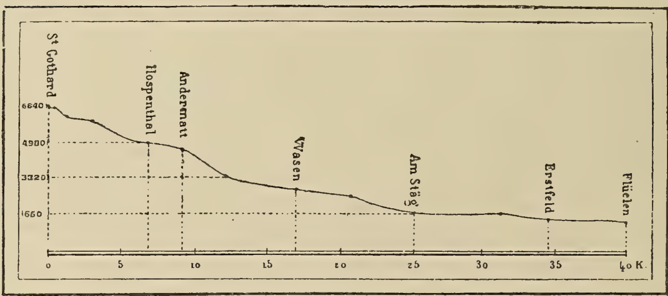
above the level of the sea, and descend first through a very steep bed, sometimes intersected by precipices, or even interrupted by lacustrine basins. On reaching the lower plains, the running water, now converted into a considerable river by the tributaries which have joined it on both sides from the valleys of the mountain system, extends in long and peaceful windings across the more or less sloping ground which serves as a pedestal for the mountain-chain. This is its middle course, during which the river receives its principal affluents descending from other mountain-chains, or the high ground which commands it laterally. Then, below the last hills, its lower course begins; the fresh water descends slowly down to the

sea, and, not far from the mouth of the river, is arrested in its course twice every day by the salt tide which meets it.

The Rhine is a magnificent example of a river in which the three divisions of its course are regularly developed. The upper course, the whole of which is included in the Alpine regions, bends round in a vast semicircle to Laufenburg and Basle, where the rapids cease. The middle course, remarkable for its regularity, rolls on uniformly to a point below Mayence, where the Rhine is compelled to open a passage across the Odenwald and other hills; then, below the Siebengebirge, between two low banks of alluvial origin, commences the lower course, which ultimately terminates in the muddy estuaries of Holland. But for one river where the three divisions of its course are marked with so much distinctness, how many there are which exhibit no marked difference between the various portions of their bed!

Fig. 112.—Slope of the Reuss; example of a Compound Valley.

Scale { Lengths, 1 : 400,000. Heights, 1 : 80,000.



How many there are, indeed, which are even calmer and less inclined on the plateaux of the interior than in the vicinity of the sea! How many there are, especially, which—as represented by some of their affluents—are entirely rivers of the plain, whilst in other tributaries which descend from the mountains they exhibit all the characteristics of torrents! These are differences essential to the fluviatile system and to its geological operations. All river-beds presenting different curvatures show by that very fact that they have taken advantage of originally distinct valleys connected together at various epochs. The more irregular the outline of their course, the more recent is the rise of the rivers themselves. A striking instance is that of the Scandinavian streams reaching the coast through successive lacustrine stages. Another instance is that presented by the Reuss Valley between Mount Saint-Gothard and Lake Uri.

CHAPTER XLVII.

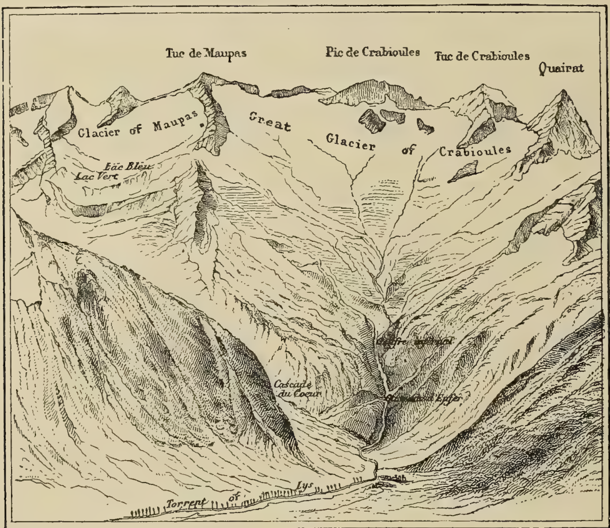
MOUNTAIN TORRENTS.—INEQUALITIES OF THEIR BEDS AND OF THEIR DISCHARGE OF WATER.—TEMPORARY STREAMS.—FILLING UP OF LAKES.—EROSIONS, GORGES, AND SLOPES.—TORRENTS OF THE FRENCH ALPS.

THE principal features which distinguish the mountain torrent from the watercourse in the plain is the irregularity of its bed, its mode of action, its discharge of water, and its sedimentary matter. Among the gentler features of the plain, the stream runs but slowly, and all the changes of slope, curve, and level take place in gradual transitions; but, on the contrary, in narrow winding gorges it is violent, impulsive, and uncertain. Rocky angles project abruptly across the water; the declivity is intersected with precipices; the liquid mass poured down by the torrent may sometimes be compared to that of a river, but at other times it forms only a slender rivulet, or even dries up altogether. Lastly, most mountain streams are sometimes as pure as crystal, and at others are loaded with so large a quantity of alluvium that they are more like avalanches of *débris*. The turns and twists of the gorges are so much the more sudden as the rocks through which they are cut are higher, harder, and more irregular in their stratification and fissures. The water dashing against some projection springs back at right angles on the opposite rock, to be again driven back, and thus descends towards the valley in a series of zigzag falls. In these rugged gorges, where the pathway seems suspended from the ledges of the opposing cliffs, on either side overhead may be seen the abrupt fissures where the torrent has cut a passage; and not only is this mass of water and foam incessantly cast from one side to the other by the obstacles which hem it in, but it is very often temporarily kept back by the barriers of *débris* which crumble down across its course. When the dam, composed of stones and blocks of rock, affords no interstices through which the water can glide, the latter gradually rises in the form of a lake, and then makes its way as a cascade over the wall of rubbish, which by degrees it hollows out down to the level of its old bed. But usually the avalanche which pens back the torrent consists of a mass of snow, dust, and broken stones; the water kept back by this more plastic dam slowly converts it into a kind of pasty mass, and forces its way through a subterranean outlet. In the spring, when a good many avalanches are falling from the sides of the Alps, it is curious to trace the course of the torrent, visible here and there, in the gorges. The water may be seen diving down under some grayish or dark mass, joining with its graceful curve the two opposite sides of the ravine. The entrance of the gulf forms a kind of porch ornamented with icicles, down which the melted snow trickles or falls drop by drop. Above the torrent which is roaring in the depths below, the

mass of *débris* is intersected in some places with *crevasses*, and the closely packed snow presents a bluish edge, like ice; wells open in it at intervals, at the bottom of which the foaming waves may be indistinctly seen careering along.

The variations which are found in the discharge of a torrent stream are really enormous, even in those mountainous countries where, owing to the accumulation of the winter snow upon the heights, the water never entirely dries up. During severe cold, when the snow above is frozen on the ground, and numbers of rivulets are converted into solid ice, the main stream of the valley sends down only an inconsiderable liquid volume, and a traveller may easily cross it by jumping from stone to stone; but on the arrival of the earliest warm weather, when the rain and the sun, assisted by the south wind, melt the snow and cause it to slide down in avalanches, the masses of water which are discharged into the torrent from all sides

Fig. 113.—Cirque of the Valley of Lys.



change it into a formidable river, running sometimes, Surell tells us, at a speed of 46 feet a second—more than 30 miles an hour. It spreads out widely over its basins, flows over the meadows, and often washes away farmhouses, trees, and even the vegetable mould. In the defiles, on the contrary, it is compelled to gain the requisite space in height, as it cannot find it in width, and its level suddenly rises 60, 80, or even 120 feet. All this may easily be noticed in the narrow Italian valley-streams fed by the snow from the Mont Blanc and Monte Rosa groups. The Sesia, the Dora, and many of their affluents, before they empty into the plain, pass through dark gorges, where the liquid mass of the flood-water, ten times deeper than its width, descends with the rapidity of an avalanche. Looking forward to these rushes of water, the mountaineers, in many places, have dug out their paths more than 150 feet above the bed of the torrent.

The Var may be mentioned as an instance of this astonishing fluctuation in the

discharge of its torrent-waters. At its outlet, the liquid mass of this river varies from 37 to 5,240 cubic yards of water in a second; this difference is as 1 to 143, and the proportion would be still larger if the fluctuations were measured above the confluence of the Vaire, the Tinée, and the Vésubie. In the level countries of Western Europe, the difference presented between the high and low-water levels is, on the average, scarcely one-tenth of that afforded by the Var. In great rivers, such as the Mississippi, the difference between high and low water is as 1 to 4 only.

Fig. 114.—The Igharghar.

As a standard of comparison between the floods of a torrent and those of a lowland river in the same climate, we may mention the Upper Loire and the Somme. Above Roanne, the basin of the Upper Loire, at its first outlet from the mountains, comprises an area of 2,470 square miles, and the stream discharges during exceptional floods 9,549 cubic yards of water a second—rather less than four yards for each mile of surface. In its highest floods, the Somme sends down 117 cubic yards of water—a quantity which, if it was spread over its drainage area, would render the floods of the Upper Loire 84 times more considerable than those of the Somme; and doubtless a comparative study of the inundations of all the water-courses in France would disclose still greater variations between the system of torrents and that of the lowland rivers.

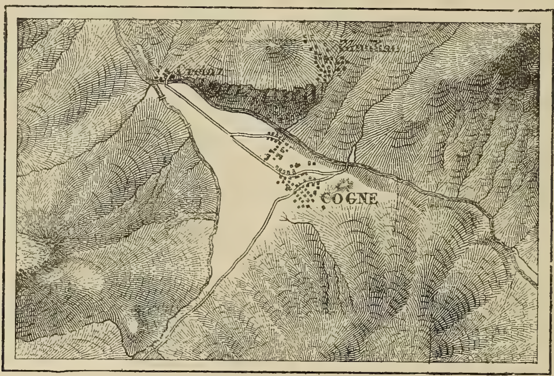
In the tropical regions, where the rainy season is succeeded by the season of drought, the greater part of the mountain rivers only run during half the year; they are alternately considerable rivers and dry ravines.

Thus, some valleys, those, for instance, of the Sierra-Nevada de Santa Marta, exhibit a daily fluctuation in the discharge of their streams, owing to the storms which the gusts of the trade-winds rarely fail every afternoon to dash against the heights. In the evening, all the gorges are filled with masses of raging water, and the traveller finds himself compelled to put a stop to his journey; he bivouacs on the edge of the river, and is lulled to sleep by the noise of the cataracts roaring over the rocks; when he wakes up at dawn next day, all he sees is a slender rivulet of water, only visible here and there among the masses of gravel.

But the torrents which must be instanced as the most striking types of the merely temporary watercourse, are the *wadys* in the Sahara and the plateaux of Arabia, and the liquid masses which sometimes roll down the *quebradas* of Bolivia and the Argentine *pampas*. All round the Red Sea, embracing an extent of more

than 1,550 miles of coast-line, there does not exist one permanent stream. All the *wadys* which, during heavy rains, flow into the sea, convey to it only the surplus of the surface-water which the sand of the desert was not able to absorb. In a general way, before the complete disappearance of these streams, most of which run over a bed of subterranean rock, they ooze up imperceptibly through the sand, and show themselves in pools stagnating in the passes of the defiles.

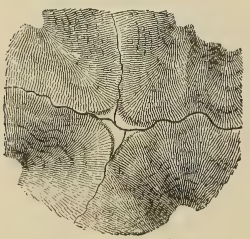
Fig. 115.—Valley of Cogne.



Instances of streams thus converted into a chain of ponds are very numerous in deserts all over the world—in Arabia and Algeria, in the Caspian steppes, and in the North American solitudes.

In these regions the ground on the plateaux and in the plains is furrowed with valleys exactly like those found in a country that is well watered with rivulets, streams, and rivers. The river system exists in full force, and for hundreds of miles the traveller may trace wide hollows, perfectly developed, which would contain rivers like the Danube or the Rhine, and on either side debouch the stony stream-beds of the lateral valleys. Nevertheless, these deep and winding depressions, hollowed out by the temporary watercourses, generally contain nothing but pebbles and sand; water is altogether wanting, except during the season of the periodical rains. One of these waterless rivers, the Roumah, which connects its bed with the Euphrates, not far from the mouths of the Chat-el-Arab, is not less than 750 miles in length. The only permanent elements, so to speak, of its vast drainage area are a few springs and rivulets flowing from the mountain-sides round the circumference of its basin.

Fig. 116.—Quadrangular Basin of Erosion; after Sonklar.



In the upper part of their course, these torrent-waters assist, as we have said, in modifying the relief of the terrestrial surface; but these magnificent operations of erosion, which crumble away mountains, or, at least, by enlarging the clefts, ultimately convert mere fissures into openings of such important dimensions both

in width and depth, are not the work of the torrents alone. The latter, in fact, are scarcely the chief agents in the work; they do little else than clear away the stones and *débris* fallen from the heights above. All the meteoric phenomena of the atmosphere—among which, however, snow and rain may certainly be considered as the real origin of torrents—contribute to the work of destruction, and detach from the mountain-sides masses of *débris*, which accumulate at the foot of the rocks in more or less inclined slopes. The torrent into which this *débris* crumbles down washes away all the sand and lighter matter, until the time when, swelled by rain and melted snow, it rolls down towards the valley the great blocks of rock that have fallen into its bed. It is difficult to restrain a feeling of dread when we pass along the bank of a flooded torrent and hear, above all the uproar of the water, the dull thunder of the masses of stone dashing one against the other as they are hurried along under the rushing water, yellow with the earth which it washes away.

Thus, year after year, and century after century, the torrent clears away whole mountain-sides which have crumbled down into it rock by rock, and this great work of erosion is incessantly going on. In some mountain groups, where the rocks are easily shifted by the action of the weather, nothing is left but a mere skeleton of those former proud heights which once towered up towards heaven. But in the regions where the mountain strata are of a compact formation, and the water consequently takes some considerable time to penetrate them, all that we notice in the way of dilapidation are large holes which the torrents have gradually hollowed out in the body of the rock. Where two mountain rivulets form a junction, it is very seldom that the three headlands which overlook the confluence do not leave at their base a small triangular valley, whence the water leaps down into the lower gorge. In like manner, when two streams proceeding from directly opposite ravines fall into the main stream of the valley at the same spot, the little plain of erosion which is found at their confluence generally assumes a quadrangular form. It must, however, be understood that the dimensions and the outlines of these basins must vary infinitely according to the force of the torrents, the hardness of the rocks, and the energy of the agents that attack them. Ultimately, the surface of the country having been carved out by the water for an unknown number of centuries, completely changes its aspect; the mountains and the plateaux are swept down by the rivers, and little else remains but the isolated landmarks of the ancient piles.

There is probably no country in the world where this devastation goes on more rapidly than in the French Alps. The mountains of this region, and especially those which enclose the basins of the Durance and its tributaries, are in general composed of very hard rocks, alternating with other beds, which easily give way under the action of the water; in every place we may notice immense cliffs resting upon bases without any solid consistence. The marls, the disintegrated schists, and the other friable matter, are gradually washed away, and their fall precipitates that of the compact layers at the summit, which suddenly fall down or glide slowly into the valleys. It is, however, the improvidence of the inhabitants, and not so much the geological constitution of the soil, which is the principal cause of the devastating action of the streams. In the mountains of Dauphiny and Provence, the slopes, most of which are now so bare, were once covered with trees and various plants which kept back the surface-water resulting from the rain or melting of the snow, by absorbing a great part of the falling moisture, and thus retaining the coating of vegetable earth over the beds of crumbling rock. During the course of

centuries, the trees have been cut down by greedy speculators, and by senseless farmers who wished to add some little strips of land to the fields in the valleys and to the pastures on the summits; but when they destroyed the forest they also destroyed the very ground it stood on.

The rain or snow, being now no longer kept back upon the slopes by the roots

Fig. 117.—Valleys of Erosion in Burgundy.

of the trees, descends rapidly into the valley, driving before it all the *débris* torn away from the sides of the mountain. The tooth of the goat and the sheep helps to lay bare the rootlets of the herbaceous plants and the brushwood; bit by bit, the whole of the thin coating of vegetable earth is removed, the bare rock shows itself, and deep ravines are hollowed out in the cliffs and are traversed in the rainy seasons by furious torrents which once did not exist. The water which used slowly to

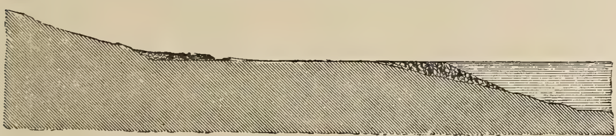
penetrate the earth, conveying fertilizing salts to the roots of the trees, now serves no other purpose than that of devastation. When the forests are gone, great furrows of erosion may be noticed opening out at intervals on the slopes; these furrows often correspond to ravines situated on the other side of the mountain, and in a comparatively short space of time, they ultimately sever the ridge of the mountain into distinct peaks, uniformly surrounded by a slope of rocks or fallen earth; summits of this kind are being formed every year. In some localities, there is not a single green bush over a space of several leagues in extent; the scanty gray-coloured pasturage is scarcely visible here and there on the slopes, and ruined houses blend with the crumbling rocks that surround them. The stream in

Fig. 118.—Talus of Débris in the Valley of the Adige.

the valley is generally nothing but a scanty rill of water winding among the heaps of stones; but these very heaps of shingle and rock have been carried down by the torrent itself in the days of its fury. In many parts of its course, the Upper Durance, which is generally not more than 30 feet wide, seems lost in the midst of an immense bed of stones, a mile and a quarter wide from bank to bank. The Mississippi itself does not equal it in dimensions.

The devastating action of the streams in the French Alps is a very curious phenomenon in an historical point of view; for it explains why so many of the districts of Syria, Greece, Asia Minor, Africa, and Spain have been forsaken by their inhabitants. The men have disappeared along with the trees; the axe of

Fig. 119.—Talus formed by Torrents.



the woodman no less than the sword of the conqueror have put an end to or transplanted entire populations. At the present time, the valleys of the Southern Alps are becoming more and more deserted, and the precise date might be approximately estimated at which the Departments of the Upper and Lower Alps will no longer have any home-born inhabitants. During the three centuries that have elapsed between 1471 and 1776, the *vigneries* of these mountainous regions have lost a third, a half, or even as much as three-quarters of their cultivated ground; and the men have disappeared from the impoverished soil in the same proportion. From 1836 to 1866, the Upper and Lower Alps have lost 25,000 inhabitants, or nearly a tenth of their population. At the present time, in an area of 3,860 square miles, embraced between Mont Thabor and the Alps of Nice, there is not

a single group of inhabitants which exceed the number of 2,000 individuals. Barcelonnette, the most considerable place, has more than once been in danger of being carried away by the stream, the bed of which is higher than the streets of the town; the latter certainly would be still less populous were it not that the numerous functionaries necessary in every sub-prefecture tend to give it an artificial life. Without the *employés* and the custom-house officers, who almost consider themselves as exiles, the whole extent of a great portion of these mountainous regions would be nothing more than a gloomy solitude. It is the mountaineers themselves who have made and are seeking to extend this desert, which separates the tributary valleys of the Rhone from the populous plains of Piedmont. If some modern Attila, traversing the Alps, made it his business to desolate these valleys for ever, the first thing he should do would be to encourage

Fig. 120.—Ancient Lakes and Defiles of Aluta.

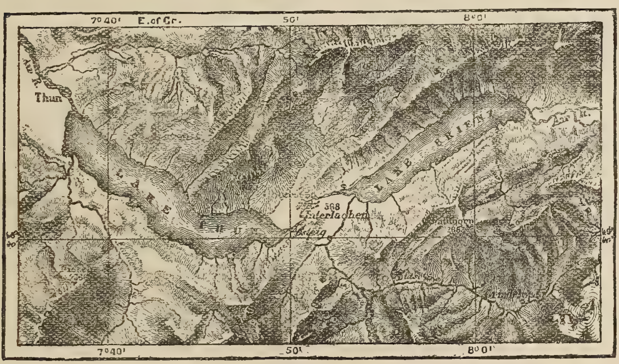
the inhabitants in their senseless work of destruction. Is it necessary that man must ultimately rid the mountains of his odious presence, so that the latter, left to the kind offices of beneficent nature, may again some day recover their forests of fir-trees and their thick carpet of flower-studded turf?

Although the torrents lower the mountains, on the other hand they elevate the plains; but their deposits, not being pulverized into clays and sand, are often the means of bringing another disaster on the inhabitants, who find their fertile land covered beneath enormous masses of rocks and shingle. In fact, when a stream empties itself into a valley which has a moderately inclined slope, and the former consequently experiences a sudden check in its progress, it deposits over a long extent of descent all the *débris* which it conveys in its water or rolls down before it. The masses of rough alluvium accumulate on both sides of its course, so as to form a rising, with regular slopes abutting against the escarpments of the mountain. Even in places where the stream once rushed down into the valley in

rapids or cascades, its tendency always is to conceal gradually every irregularity in its old bed under the ever-increasing slope of rocks, pebbles, and sand. The deep ravine of the upper valley is succeeded by a long embankment, which, continuing the incline, pushes out far into the principal valley, and forces the stream to describe a considerable bend round the base of the cone of *débris*. Some of these banks attain very important dimensions; they accumulate to an enormous extent at the outlet of each lateral ravine opening into the elevated valley of the Adige, to the south of the Œtzthal group. One, that of the Litznerthal, is 1,036 feet in height at the outlet of the ravine, and extends 4,148 yards in length as far as the Adige, with a mean slope of 4° 46′; the curve of the river which winds round its base is not less than five miles in length.

When the streams empty their waters into a mountain lake, and not into a valley, the *débris* which they carry down accumulates at the upper end of the lacustral basin, forming a slope much more abrupt than the mass of stones deposited at the entry of a ravine. In fact, at the outlet of the latter the water of the torrent continues to flow over the masses which it has heaped up; fresh materials are

Fig. 121.—Lakes Thun and Brienz.



continually being brought down, some of a small, others of a large size, which serve both to prolong the slope and to render it more and more uniform with that of the plain below. In lakes, on the contrary, a separation immediately takes place in the various *débris* brought down by the current. The blocks of stone and pebbles fall by their own weight into the depths of the water, and form a kind of *moraine*, which incessantly pushes on into the quiet water. The lighter alluvium, which is held in suspension by the liquid mass, is partially carried on by the current towards the middle of the lake; but the greater part of this matter is soon dropped on each side of the *embouchure*, and ultimately extends in horizontal promontories above the accumulated mass of heavier rubbish. Thus, the bed of the stream, with its steep slope of stones in front, bordered by its layers of lighter alluvium, incessantly encroaches on the lake.

A large number of lakes have thus been gradually filled up altogether; in several high mountain valleys, where lakes exist at intervals one above another, all the basins have in turn been filled up. In other places the upper pools only are choked, and the work is going on in one of the lower lakes, which, sooner or later,

will ultimately be converted into a horizontal plain. By very carefully measuring the annual deposits of a torrent, and ascertaining, by boring, the depth of the former lakes which they have filled up, the number of centuries might be approximately estimated which this immense work has taken. Also, sounding the depths of the basins which are still full of water would show the duration of ages which will be required to fill up their abysses. At the foot of the great group of the Bernese Alps, on the isthmus of Interlachen, so well known to travellers, it would be comparatively easy to make the experiments necessary for the solution of this problem, which would also inform us approximately as to the duration of the geological period during which the streams have flowed down from the mighty group over which towers the Jungfrau. For this calculation it would be necessary to measure the present deposits of the furious Lutschine, and to estimate the enormous solid mass of the isthmus of Interlachen which has been thrown down by the stream as a kind of dam between the two lakes of Brienz and Thun, which once formed only one lacustrine basin. But, as remarked by Viollet-le-Duc, it should be remembered that, immediately after the glacial epoch, the masses of alluvia washed down from the uplands were spread like molten lava in vast quantities over the plains. In estimating the amount of these alluvia, which have divided the lake into two basins, geologists have to distinguish between the glacial and more recent sedimentary deposits.

CHAPTER XLVIII.

EROSION OF LACUSTRINE DIKES.—CATARACTS AND RAPIDS.

WHILST crossing the lakes situated at the bases of the mountains, the waters of the torrent become tranquillised, and their course regulated; they emerge from the basin in streams of a less turbulent shape, and flowing on to join other watercourses, descend with them quietly to the sea.

But even the outlet-stream of the lake, although usually more peaceable than the watercourse above, accomplishes its special geological labour, and is also employed in the task of doing away with the lacustrine basin. The water, impelled by its own weight, constantly wears away the layers which form the lower margin of the lake. The edge of this margin being gradually destroyed by the liquid mass, sinks by slow degrees, and the average level of the water in the lake sinks also in the same proportion. Thus, at the two extremities of the basin the river is carrying on two kinds of work, contrary in appearance, but which

Fig. 122.—Filling up of a Lake-basin.

have both an equivalent result in reducing the area of the lake which the river crosses. Up above, it gradually elevates its bed, and gains on the lake by filling it up with alluvium; down below, it lowers the brink, and, by this constantly increasing waste-gate, gradually drains out the water. The two stream-beds, the upper and the lower, will ultimately meet in the middle of the lake, and the latter will cease to exist. This is the double phenomenon which has been going on for ages in the Lake of Geneva. This crescent-shaped sheet of water certainly once extended as high up the stream as the place where the town of Bex now stands, 11¼ miles from the end of the lake; it also extended down the stream in narrow basins as far as Ecluse, 9½ miles from the outlet of the Rhone.

It must, however, be understood that the outlets of lacustrine reservoirs are not the only places where the rapids and cataracts of a river crumble away the rocks so as to lower the up-stream and elevate the down-stream beds. However hard may be the strata which form the bed of a rapid, the eddying waters ultimately pene-

trate the stone, and deposit the *débris* below the gulf that the furious shock of the torrent has hollowed out at the foot of the rocks. In like manner, cascades and cataracts incessantly wear away the ledges from which the mass of their water pours down to the bottom of the abyss, carrying the great stones with them in their fall, and, destroying layer after layer, they continually retrograde towards the source of the river, and tend to convert themselves into mere rapids, which, in some thousands of years, or perhaps centuries, are destined to assume a perfectly uniform inclination. This is the ideal, so to speak, of every river—to do away with the irregularities of its course, and to flow down towards the sea, describing a regular parabolic curve. This ideal, however, is never perfectly attained, on account of the diversity of rocks in its course, the changes in its bed, the disturbances or elevations of the ground, and other circumstances of various kinds which may cause a deviation in its current. But whatever may be the obstacles which oppose the levelling of the declivity, still

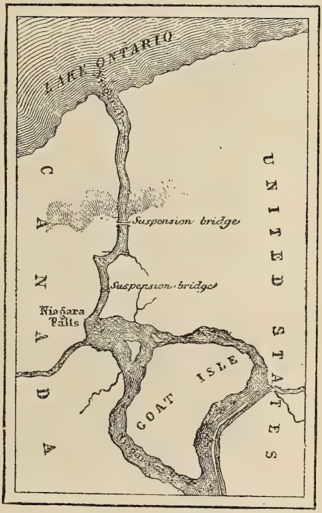
Fig. 123.—Alluvial Deposits of the Rhone and the Dranse.

every river intersected by falls and rapids is constantly at work in effecting the general uniformity of its slope.

In their magnificent beauty, cataracts and rapids yield the pre-eminence to hurricanes and volcanic eruptions alone. Of the former, there are some in Europe which are very remarkable, such as the falls of the Rhine at Schaffhausen; the four cataracts of the Gotha-Elf at Trollhäta (dwelling of sorcerers); the Hjommel-saska (the hare's leap), where the river Lulea plunges over in a body from a height of 264 feet; and the Riukan-fos (roaring cascade), which falls at the outlet of the Norwegian lake Mjösvand in a single jet of 885 feet. The most celebrated waterfall in the whole world is that of Niagara—"the falling sea"—the constant thunder of which may sometimes be heard 12 miles off. Above the cataract the river, which discharges on the average 1,300 to 1,400 cubic yards of water a second, breaks against the shore of Goat Island, and divides into two rapidly inclined currents. Even at this point the mass of water is impelled by such velocity of movement that engineers have not yet been able to sound its depth, and they have similarly failed to do so below the cataract. On reaching the edge of the cliff, the two halves of the river—one 655 and the other 295 yards wide—take their final leap, and describe their vast parabola, 147 feet and 160 feet in height. A gloomy passage,

penetrated by furious gusts of wind, opens between the wall of rock and a sheet of water, 18 to 33 feet in thickness, which curves widely overhead like an immense arch of crystal. Columns of iridescent vapour spring from the whirlpool of the roaring waters, and half hide the two white masses of the cataracts. At every instant of the day, following the path of the sun, the great rainbow painted on the wavering and misty sprays shifts its position and thus modifies the aspect of the fall. The various seasons, each in their turn, add some feature of beauty to the magnificence of the spectacle. The trees still left on Goat Island and the cliffs contrast with the whiteness of the water—in summer by their verdure, in autumn by the more varied colours of their foliage. In winter, stalactites, glittering in the sunlight like immense strings of diamonds, hang down from all parts of the rock, and serve as a framework to the two great plunging sheets of water. In spring, when the ice breaks up, a formidable spectacle is presented by the blocks of ice, like mountain fragments, crowding together at the edge of the cataract, and crashing against one another as they glide over the enormous curve of water which is sweeping them along.

Fig. 124.—Course of the Niagara.

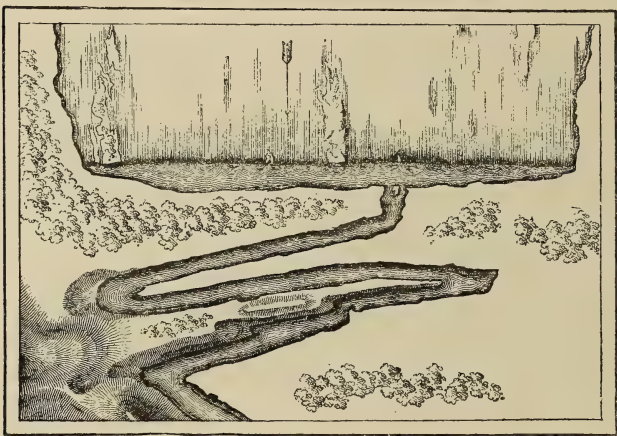


Other great waterfalls in different parts of the earth afford similar phenomena, and several of their number may even rival Niagara in their beauty. Among these we may mention, in North America, the magnificent falls of the Missouri, the Columbia, and the Montmorency. Of like beauty, also, there is in Brazil, not far from Bahia, the wonderful cataract of San Francisco, known by the name of Paulo Affonso. At the foot of a long slope over which it glides in rapids, the river, one of the most considerable of the South American continent, whirls round and round as it enters a kind of funnel-shaped cavity roughened with rocks, and, suddenly contracting its width, dashes against three rocky masses reared up like towers at the edge of the abyss; then, dividing into four vast columns of water, plunges down into a gulf 246 feet in depth. The principal column, being confined in a perpendicular passage, is scarcely 66 feet in width, but it must be of an enormous thickness, as it forms almost the whole body of the river. Half-way up, the channel which contains it bends to the left, and the falling mass, changing its direction, passes under a vertical column of water, which penetrates through it from one side to the other, and breaking it up into a chaos of surges, converts it into a sea of foam. Sometimes the white misty vapour may be seen, and the thunder of the water may be heard, at a distance of more than 15 miles.

This turbulent cataract is very different in character from the majestic falls of the Zambesi, the existence of which Livingstone has made known to the world. Above the precipice the river is calm, and flows over a gently inclined bed; some islets, covered with cocoa-nut trees, are reflected in the clear water. A large island, called "The Garden," on account of its rich vegetation, divides the Zambesi

into two branches, and the general features of the landscape are full of grace. All on a sudden, without the least transition, the ground comes to an end beneath the water, and the two liquid masses, one of which is 1,858 and the other 546 yards wide, plunge down to a depth of 348 feet into the gaping fissure of a vast mass of basalt. They then escape by a narrow and winding channel, which the river itself has hewn out of the rock during the lapse of many centuries. Ten columns of vapour, answering to ten great projections on which the body of water dashes itself to pieces, rise in eddies from the foot of the precipice, and float, like the smoke of a conflagration, far away above the surface of the river. They vary in height according to the state of the water and the atmosphere; but, generally speaking, they do not rise less than 1,000 or 1,150 feet above the brink of the gulf. On account of these clouds of spray and vapour, the natives have given

Fig. 125.—The Falls of the Zambesi.



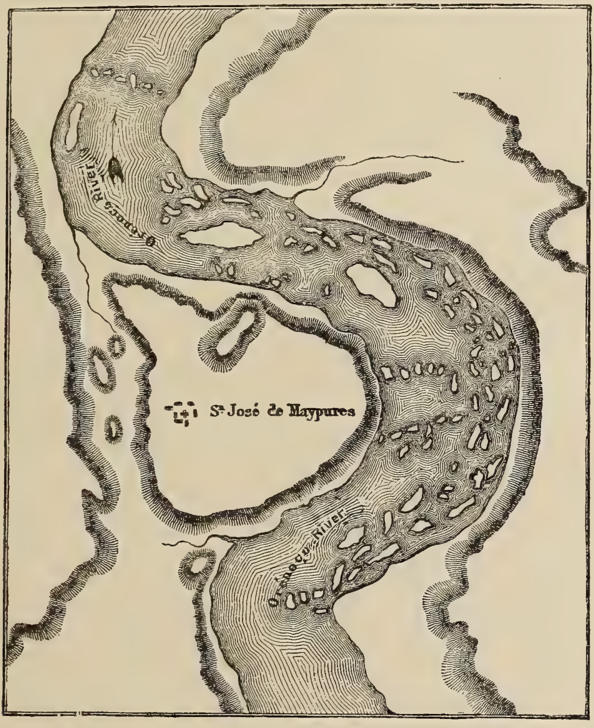
to the cataract of the Zambesi the name of *Mosi-oa-Tounya*, or "Thundering Smoke."

With regard to rapids, we find them on most rivers at different points of their course, either at spots where cataracts once existed, or at the mouths of streams which carry down with them large quantities of *débris*, and pile them up like dikes across the current. The American rivers are the principal localities where these rapids may be contemplated in their full beauty. Humboldt was the first to describe the *raudales* of Atures and Maypures, where the Orinoco, changed into a mass of foam, pours down innumerable cascades over a chaos of rocks and banks with dark sides crowned with foliage and verdure. Each mass of granite, resembling in its shape some ruined tower or castle, is surmounted by a group of palms or densely-foliaged trees. Every stone below the level which the river reaches during flood-time is covered with alluvium, on which the mimosa, with its delicate leaves, grows abundantly; also ferns and orchids, with their charming flowers. They are perfect little gardens surrounded with foam, reminding one of the rocks covered with flower-studded turf which spring up in the midst of some of the glaciers in

Switzerland. A cloud of vapour hovers over the river, and the rainbow shines through the verdant hues of innumerable bowers of foliage. This is the lovely spectacle which the Orinoco affords for a distance of several miles along each of its two rapids. The fall is not considerable, that of the *raudal* of Maypures being scarcely 30 feet; but still the slope is very difficult to overcome, and in a width of 2,841 yards the navigable channel is sometimes not more than 18 feet.

About the same time as that when Humboldt and his friend Bonpland visited the rapids of Atures and Maypures, Azara examined the great *salto* of Maracayu,

Fig. 126.—Rapids of Maypures on the Orinoco.

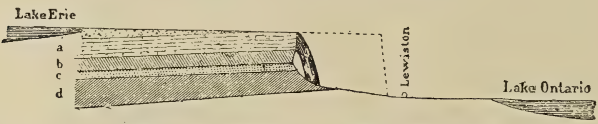


where the river Parana, which, just above, is 4,590 yards wide, is suddenly contracted into a deep channel only 66 yards across, and sliding over an inclined plane of 60°, forms a fall of 56 feet of vertical height. The narratives of travellers have also made us acquainted with the rapids of the Madeira, the Huallaga, the Ucayali, and several other rivers, down which the canoes of the savages used to glance like arrows in the midst of the foam. In North America the most celebrated rapids are those which the St. Lawrence forms at its issue from Lake Ontario; but all-powerful steam has succeeded in overcoming them. The European rapids are not so imposing, on account of the inferior quantity of the river discharge, and also

because the general relief of tne continent is much more gentle than that of the New World. We may, however, mention the rapids of the Shannon, above Limerick; the *porogs* of the Dnieper; and the whirlpools (*strudeln*) of Bingen, which were so dangerous before the rocks were blown up, that they impeded the course of the Rhine. Among the most imposing rapids in France, both on account of their bulk and the fury of their foaming water, and also of the calm solemnity of the surrounding landscape, are those of the Gratusse, formed by the Dordogne, some miles above Bergerac.

In surveying both falls and rapids, there is one point that especially impresses the mind; it is that, in a general way, immediately the water has emerged from its state of turbulent effervescence, it assumes an unbroken surface, and spreads out into wide calm sheets, known in Spanish America under the name of *remansos*. On one side we look down on the giddy chaos of the liquid masses dashing against one another as they rush along; on the other we see a pool of water almost still, or at most slowly rotating. Here, the long gentle eddies seem unable even to move the straws and twigs which incessantly float round and round in the same circle; higher up the stream, the river in its impetuous career sweeps away trunks of trees, tears up the stones of its bed, and notches out the edge of the cliff over which it falls. This contrast becomes still more striking when we reflect that the cataract

Fig. 127.—Cataract of Niagara; after Marcou.



a Limestone of Niagara 86m. c Marl of Niagara 24m.
b Clinton Group 9m. d Sandstone of Medina 90m.
----------- Part of the strata eroded by the Falls.

once descended at the very spot where this tranquil sheet of water now lies, and that during a long course of ages the fall has continually retrograded. The high vertical rocks which hem in the two banks of the river belong to the same geological formation, and the parallel lines of their strata exactly correspond on both sides. The traces of the current which has eaten away the stone are still visible, and the marks of the work slowly accomplished by the water can be distinctly traced out by the eye. The immense cavity which extends like a dark passage below the fall has been hollowed out by the cataract, scooped out, so to speak, grain by grain.

The rate of speed at which the fall shifts its position might serve to estimate approximately the age of the river itself. If geologists had studied this retrograde movement for a sufficient number of years, they would know the exact degree of resistance afforded by the rocks throughout the whole length of the cavity; they would be able to say with certainty how many centuries the present system has lasted with regard to every river which is interrupted in its course by a cataract. But this comparative study of waterfalls has scarcely commenced, except, perhaps, in the case of Niagara and some other of the great watercourses of North America. According to Hall, Lyell, and other geologists, the Falls of Niagara have receded three miles and a half in the space of about 35,000 years. Lyell states that the erosion of the edge of the precipice is now taking place at the average rate

of 12·183 inches a year, while according to Bakewell the Falls have retreated at the yearly rate of nearly a yard since 1790. This is a tolerably rapid movement of retrogression, which, however, is explained by the nature of the rocks; these latter are composed of calcareous strata resting on beds of soft and friable marl. The water penetrates into these layers, and slowly undermining them, washes them away, thus throwing down the upper strata in massive blocks, which are carried away by the cataract. The observations of M. Marcou have established the fact that the volume of water is constantly diminishing in the fall on the American side, and that, in consequence, the rocks there have scarcely been encroached upon for some twenty years. To make up for it, the great cataract is rapidly receding up stream, and even now it no longer assumes the graceful semicircular form which obtained for it the name of the "Horse-Shoe Fall." In an interval of time, which may be estimated at eight or ten centuries, the cliff of the cataract will probably be lowered as far back as the little islets of the Three Sisters; the whole liquid mass will then rush down the current which runs along the Canadian shore, and the branch on the American side, no longer receiving any water, will gradually dry up; Goat Island will become united to the mainland, and the River Niagara, constantly receding towards Lake Erie, will pour down the whole of its water in one formidable fall.

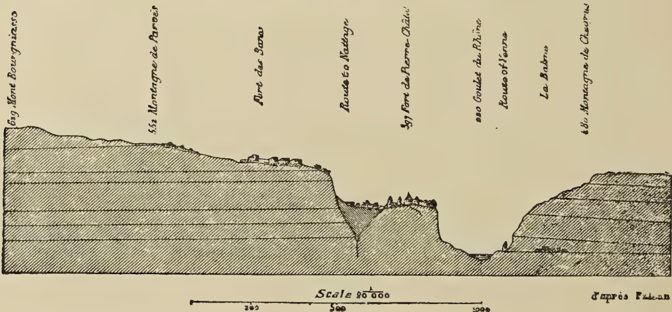
It may likewise be presumed that the height of the cataract will tend to increase; for the calcareous strata which gave way under the weight of the water gradually augment in thickness in the up-stream direction. But we are scarcely warranted in estimating, even approximately, the time which the Niagara will take in receding to Lake Erie; for, as M. Marcou remarks, the prodigious manufacturing activity of the Americans may much modify matters in this respect. A canal, which is, in fact, a perfect river, already turns a large number of mills on the American side; and if the river is tapped by thirty or forty conduits of this importance, the mighty Niagara will become nothing but a humble rivulet. "Arts and manufactures will have disarmed the thundering Jupiter." But Lake Erie itself, which, according to Ellet, contains at present more water than the fall could run off in six or eight years, will be perhaps filled up with alluvium before Niagara has been able to wear away the lower ledge of rocks which prevents the lake from rushing down bodily into the basin of Ontario.

What the future may perhaps accomplish as regards Niagara, has already taken place in the Mississippi. Nearly half-way between St. Louis and Cairo, the river penetrates a defile which cuts through the chain of the Ozark Mountains; rocks, 300 feet in height, rise between the two banks, and on their perpendicular sides may be clearly distinguished the lines of erosion which were once traced out by the current of the Mississippi. In former days these rocks formed a barrier over which fell a cataract like that of Niagara, which, too, like the former falls, constantly wore away the strata which served as its bed. Above this barrier of hills, the water of all the upper tributaries united in a vast lake, which extended north as far as the mouth of the Wisconsin, and joining Lake Michigan on the east, covered all the immense prairies of the intervening peninsulas. In like manner, the Rhine, the Danube, and a great many other rivers, the course of which at the present day is tolerably uniform, presented a succession of lacustrine ponds, placed in gradation one above another, and united by cascades. The rocky barriers situated between the ponds have been gradually demolished and washed away by the water; some of them have even been pierced through at their base, and this is the origin of the natural bridges which throw their arches above a

great number of streams and rivulets. The Pont-de-l'Arc, which the water of the Ardeche has slowly bored out during the course of ages, has a span of not less than 177 feet. The famous natural bridge of Virginia is only 111 feet in width.

By operations of this kind, rivers gradually regulate their slope and effect a communication between plateaux of different heights, which sink in successive gradations from the base of the mountains to the sea-coast. Whatever may be the irregularities of the continental surface, running waters cut out their beds in the form of inclined planes, and give them a more or less regular slope, which is followed by merchandise, travellers, and even civilization itself, in order to penetrate into the separate basins of the river system. Every cut made by a river across a chain of hills or the side of a plateau, may be considered as a gate opened through a wall dividing two distinct regions. Thus, in studying the monography of each river, it is necessary to study specially the apertures which the water has made through the barriers which once opposed its free course. By a succession of victories obtained over enormous masses of rock, the river has succeeded in emerging from the lacustrine reservoirs where its waters once lay dead, and has

Fig. 128.—Section of the Rhone Valley.



gradually constituted itself as a living individuality ever at work shaping anew, with its waves, its alluvium and the bars at its mouth.

Oftentimes, when the river thus cuts away a passage through a rocky barrier, it leaves standing erect, as an evidence of the former state of things, an islet of hard stone which it has failed in washing away. In the most picturesque parts of their course, almost all large rivers exhibit some of these solid masses which continue to resist the pressure of the water some centuries after the destruction of the surrounding strata. Thus, on the Danube, we find those proud rocks, with their perpendicular sides towering up, like enormous pillars, as high as the level of the rising ground by the river-side, and crowned on their summits, some with a feudal fortress, some with a hermitage, and some with nothing but a clump of bushes or brushwood. Thus, too, in the Mississippi, not far from the spot where the whole body of its water once poured over a precipice in a mighty cataract, we notice the fine rock which, from its form and majestic aspect, has obtained the name of the "Great Tower." This rock still bears, at a height of 132 feet, the circular line of erosion which was once traced out by the current. But most of these natural water-girt "towers" have gradually disappeared, and their place is now marked only by hidden reefs or rocks on a level with the stream.

CHAPTER XLIX.

FORMATION OF ISLANDS.—RECIPROCITY OF CURVES.—WINDINGS AND CUTTINGS.—SHIFTING OF THE COURSES OF AFFLUENTS.

IT is, therefore, a fact that rivers, like all other natural agents, never cease in their work of destruction; but they destroy only to reconstruct in another place. They are continually eating away rocky islets, and employing the *débris* in the formation of islands of sand. Wherever some obstacle exists in mid-stream, such as a bank of rock, the trunk of a fallen tree, or some construction of human industry, the water, suddenly arrested in its course, divides into two currents, which, being more or less inflected and retarded by a thousand local circumstances, are thrown back towards the middle of the river, where they meet, each having described its parabola. There, one portion of each current continues to descend, describing a more elongated parabola, whilst another portion flows into the comparatively tranquil space which lies below the obstacle, and gradually deposits on the bottom the sediment with which it is charged. Thus is formed the first islet, which is destined to increase by degrees, and to serve as a starting-point for a series of other islands and sandbanks which make their appearance in turn in the extent of tranquil water embraced between the parabolas of the two curved flows.

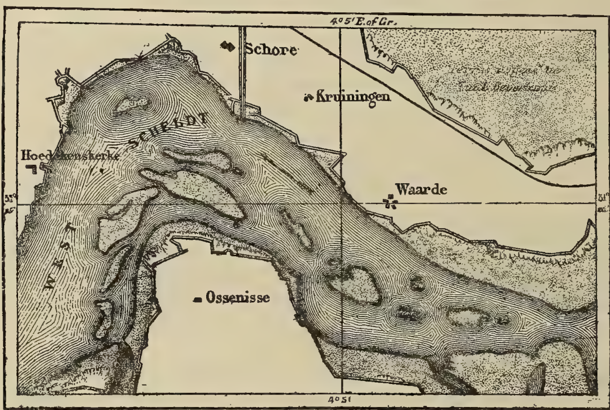
In conformity to this law of the *seriation of islands,* banks of alluvium ought likewise to emerge regularly at the confluence of two rivers; for there, also the masses of water come in collision, and being mutually repelled, again approach one another in elongated curves. In fact, the tongue of land which separates the two watercourses is often continued by a series of islets below the confluence; but the force of the current being considerably increased by the doubling of the liquid volume, and the joint bed being always much less in width than the sum of the two beds together, the stream must naturally gain in depth all that it loses in surface. The water, being confined in a narrower channel, hollows out the bed with increased energy, and thus tends to prevent the formation of sandbanks. The alluvium is deposited in the interval between the two currents, and helps to lengthen, in a down-stream direction, the "bec" or tongue of land which separates the two streams.

These chains of sandy islets would always be deposited with the greatest regularity if the river descended to the sea in a straight line. It is true that every watercourse, in obedience to the law of gravity, seeks to scoop out for itself a rectilinear channel, so as to gain the ocean by the most rapid incline. But the irregularities of its bottom and banks considerably modify the direction of the

river, and cause it to describe a series of curves or windings, thus lengthening the total extent of its course. Thus, another law, that of the *reciprocity of curves*, is combined with the *succession of islands* in beautifying the surface and contour of a river, and in causing it to incessantly remodel the bed of the valley through which it flows by hollowing away the ground, sometimes on one side, and sometimes on the other.

Some lateral impulse communicated to the liquid mass is all that is required to throw the current of the river either to the right or to the left. If the water strikes against a wall of rock, or any other obstacle placed across the regular direction of the stream, the latter rebounds so as to form an angle of reflection equal to the angle of incidence, and, induced both by its impelling force and the general slope of the bed, it becomes more and more inflected, and describes a parabolic curve towards the opposite bank. There its current is again turned back, and again takes an oblique course across the bed of the river. When the first seriation is once brought about, the current must necessarily form a succession of

Fig. 129.—Series of Islands in the Western Scheldt.



windings, in conformity with the law of the *reciprocity of curves*, which is, in fact, nothing more than the law of the pendulum. Each oscillation calls forth an equal and isochronous oscillation in a contrary direction; each curve calls forth another curve of an equal radius and equal velocity. If the fluviatile economy was not constantly modified by the varied composition of the soil and the immense diversity of the obstacles of every kind which it meets with, the river would flow down towards the sea, always forming a series of zigzags as regular as the socillations of a pendulum.

But the mass of the current does not confine itself to merely striking against the two banks in turn; it also continually wears them away, and modifies their outline. When the water dashes against the bank with all the impetus which is communicated to it by the current and the action of centrifugal force, it tears away the earth, dissolves some of the solid particles, washes away the sand, and has a constant tendency to penetrate farther. Being then driven back towards the opposite side, there, too, it destroys and washes away the soil before it is repelled

afresh, to continue on each shore alternately its work of destruction. Thus, by a law of equilibrium, the current undermines each bank in turn, whilst its alluvium is deposited at the points of the two bends. In consequence of the succession of bends and points, the windings are sometimes almost perfectly annular. A boat leaving the upper bend describes a long curve in following the river, and when it

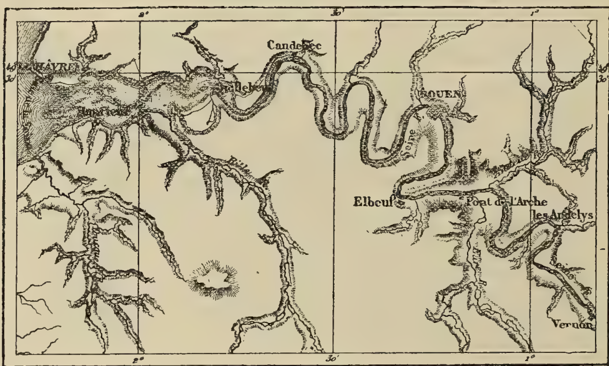
Fig. 130.—Meandering of the Meuse, at Fumay.

arrives at last at the lower bend it is sometimes actually in sight of the starting-point that it quitted long before. In the greater part of its middle course the Mississipi forms a series of windings so exactly like one another that the Red Skin Indians and the earliest European colonists were in the habit of estimating distances by the number of curves which the river described. These windings,

however, in a certain point of view, are of the very greatest utility for navigation. Every bend has the effect of moderating the slope, and thus retarding the velocity of the current, proportionately augments the mass and the depth of the water.

By dint of gradually washing away both the upper and the lower bend in a contrary direction to one another, the river constantly tends to diminish the isthmus of necks which still connects the little peninsula with the surrounding plains; thus the time will ultimately come when, the isthmus having disappeared, the two bends will be united, and the winding of the stream will be converted into a perfect ellipse. Then, unless the labour of man offers any opposition, the whole liquid mass will flow on in a straight line along the rapid slope formed by the junction of the two bends, whilst the water still remaining in the old beds will become sluggish and dead on account of the slight slope which is afforded to it by the enormous curve of the circuit in comparison to the newly-formed passage. The rapid waters of the upper bed striking against the still water in the former winding are suddenly arrested in their course, or even driven back; they then deposit the earthy *débris* that they hold in suspension, and thus gradually form

Fig. 131.—Meanderings of the Seine.

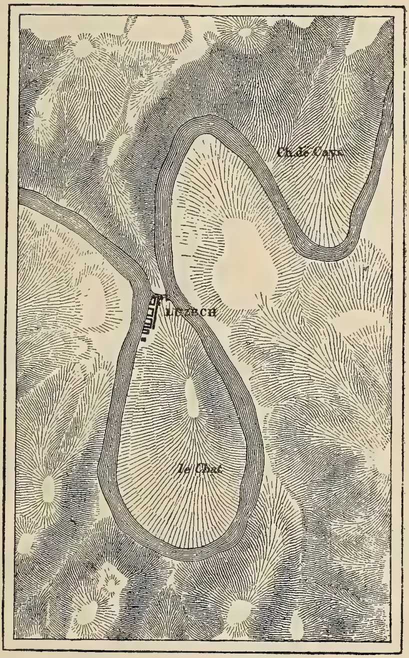


natural embankments of sand and mud between the two old beds of the river. It is not long before a similar embankment likewise separates the two beds of the lower bend, so that the forsaken winding is ultimately left without any communication with the new current of the river; its water becomes stagnant, and it is, in fact, converted into a lake. In the basins of the Mississippi, the Amazons, the Ganges, the Rhone, and the Po, there are a considerable number of these circular lakes. We may trace out with the eye, as it were, three rivers, one of which, active and living, flows without interruption from its source to the sea; whilst the two others on either side are become "dead waters." The remains of them, scattered all along the existing river, still point out the spots where once extended its ring-like windings. In consequence of these alternate shiftings of position, the valley is always much wider than its river; and along its circuitous path winds the continually changing bed of the existing stream. In some parts of its course the Po only takes about thirty years in forming and destroying each of its meanders.

The perforation of these river isthmuses is not always brought about by the

sole action of nature; many channels uniting two river-beds have been dug out by the hand of man, and, thanks to the currents which have deepened them, they have ultimately replaced the former beds. Some engineers have gone so far as to propose to carry out a systematic series of operations as regards the whole line of the Mississippi, and thus to rectify the bed of the river from Cairo to New Orleans. Since the colonisation of Louisiana the labour of man, assisting the action of the currents, has already rectified several beds; in this way have been formed the "cuts-off" of Bunch, Needham, Shrieve, Point Coupée, and Fer-à-Cheval. Above these different points the isthmuses are much more difficult to cut through, on account of the strata of compact and hard clay which extend immediately below the superficial bed of the modern alluvium, and are not easily washed away by the water. Thus it was that in front of Vicksburg a portion of General Grant's army worked in vain for several months endeavouring to cause the current of the Mississippi to pass though a channel cut across the narrow isthmus of the right bank.

Fig. 132.—Meandering of the Lot at Luzech.

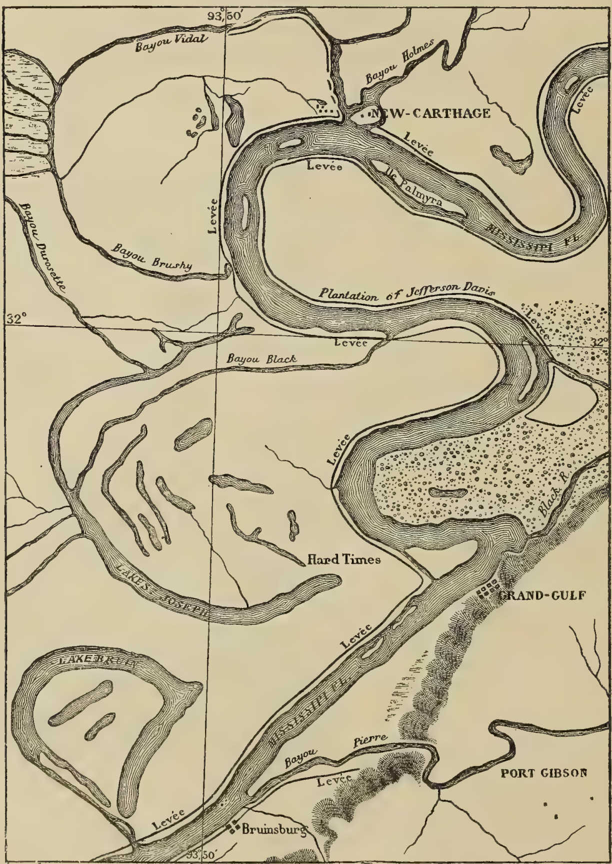


Nevertheless, all these sections formed by the hand of man cannot fail ultimately to become obliterated; for, in conformity with the law of the reciprocity of bends, a river, when deprived of its windings, soon begins to form new ones. This was the case above Compiègne, where it was vainly attempted to straighten the course of the Oise. In a very short time the river made fresh windings, the development of which was found exactly to equal those which had been done away with. It was managed better in fixing the course of the Midouze, in the Landes, for there the ingenious idea was adopted—and followed by success—of giving to the river a series of meanders of perfect regularity. When man attempts to meddle with nature, he can only succeed in permanently modifying its aspect by studying the constant laws of its phenomena, and by making his work conform to these.

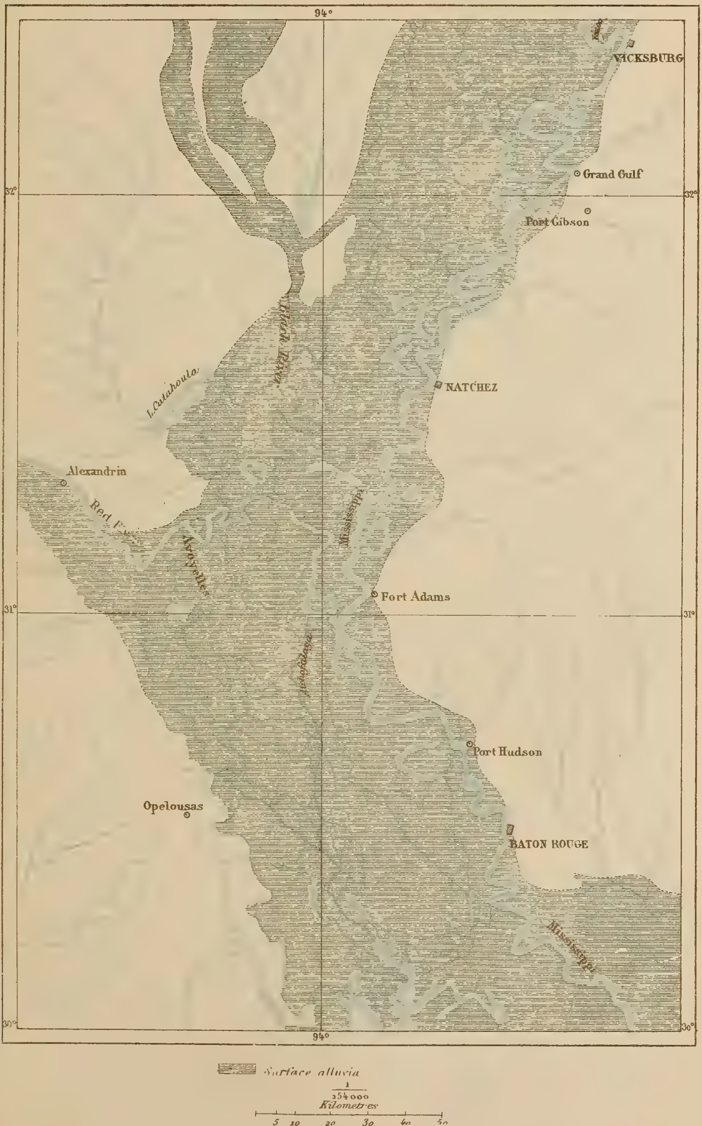
The idea of digging out and maintaining a straight channel between two parabolic bends of the Mississippi, is in no way more absurd than the idea of constructing piles, perpendicular to the current of the stream, in order to limit the bed of the river, and to throw the waters into a regular channel. By operations of this kind, contrary to every principle of hydraulics, the French engineers have entirely ruined the system of the Loire, the Garonne, and several other water-courses. The Loire—a river which is the despair of engineers, and still more of

boatmen—is distinguished above all the streams in France by the inconstancy of its current, and the continual shifting of its navigable channels. There is a very great difference between the mass of water which a river rolls down in flood-time, and the slender rivulets which slowly make their way through the sand in the dry season. Now, as a lateral shifting of the current takes place at the time of every fluctuation

Fig. 133.—Old Channels of the Mississippi.



in the level, the result is that several temporary channels are formed, and obliterated in turn. Some *mouilles*, or comparatively deep holes, are certainly to be met with almost constantly at the concave extremity of the bends, where the partial currents unite; but everywhere else the bed rises more or less over its whole extent, so as to form ridges (*râcles*), and navigation becomes impossible during a great part of the year. This fatal interruption to commerce, representing an annual loss of many



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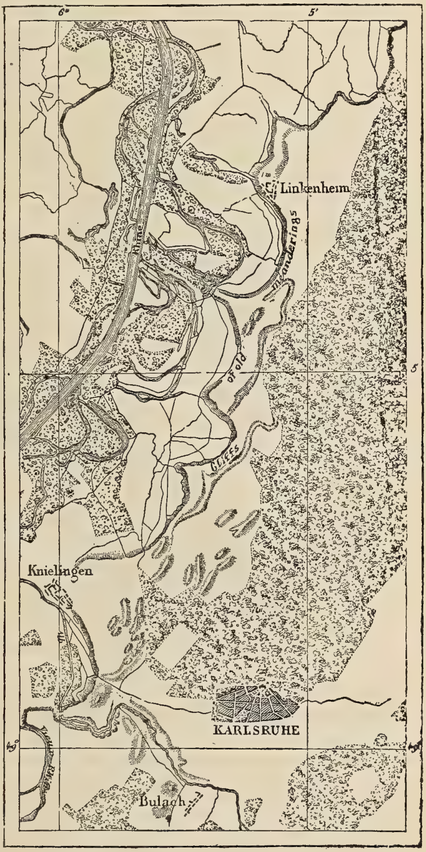
thousands of pounds, would not take place if it was decided to adopt the system of "guiding banks," proposed by M. Edmond Laporte, and subsequently by M. de Vézian. Instead of rectilinear rows of piles constructed across the bed of the river, embankments should be raised formed with a parabolic curve, against which the principal current might strike at all seasons, so as to describe unhindered its regular series of serpentine curves; this is the only plan for insuring the greatest possible depth to the channel for navigation. The diagram on p. 264, borrowed from M. de Vézian's work, points out the position which the embankments ought to occupy, and the direction that they would communicate to the current of the river.

Fig. 134.—Old Meanderings of the Rhine.

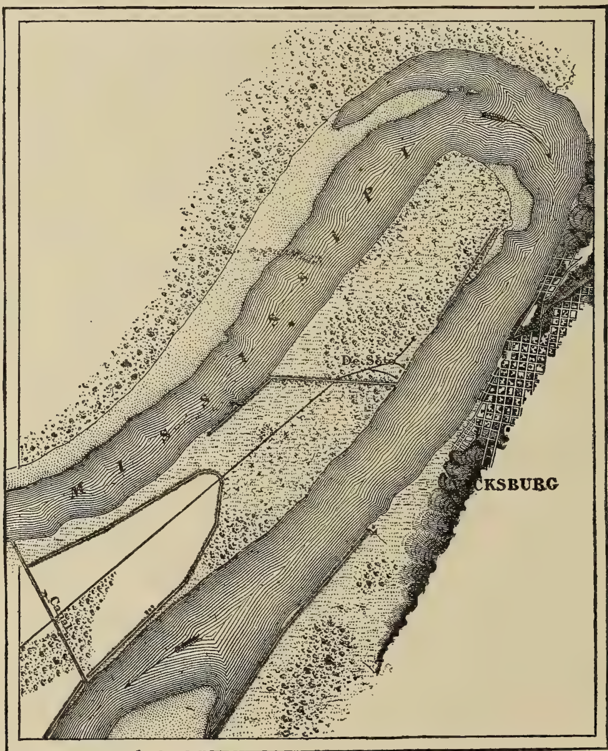


Even if the mass of water were to remain the same from year to year and from century to century, it is certain that the mere action of the current striking each bank in turn, would in the long run be sufficient to alter the curves of the river, and gradually to remodel the ground in the valley. But the liquid mass of every stream is incessantly varying from the commencement of spring until the end of winter. It increases during the rainy season, and when the snow melts; it diminishes, on the contrary, when the supply from the clouds, the snow, and the glaciers is not equivalent to the water which is absorbed by the innumerable rootlets of the vegetation by the river-side, and by the continual evaporation caused by winds and heat. Under the influence of these various phenomena which either increase or abate, the level of every river constantly fluctuates between *flood* and *low-water*. The current of the stream is consequently shifted, first to one side and then to the other, and thus every day contributes in a different way to the erosion or consolidation of each of its banks. The quantity discharged by the river during flood-times being five, ten, fifty, or even a hundred times as much as at low-water seasons, it is hardly to be wondered at that the erosion accomplished by the current should also vary in very considerable proportions.

By dint of manipulating the small particles which it has itself been the means

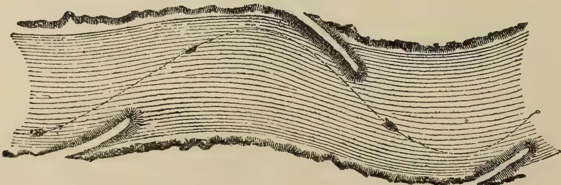
of conveying to the alluvial plains, the river ultimately succeeds in completely altering the direction of its own tributaries. The short promontories which are

Fig. 135.—Channel of Vicksburg.



situated at the confluence of the principal river and the streams which run into it, are constantly lengthened in a down-stream direction by all the sandy or muddy

Fig. 136.—Diagram to show "Guiding Banks."



débris which is deposited by the two currents. The two masses of water, which are ultimately to encounter one another, tend to take a direction more and more

parallel on each side of this increasing promontory, and developing their windings on both sides of their axis of descent, thus make their way side by side through the plains. A magnificent example of this inflection of river-beds may be noticed in the valley of the Rhine between Basle and Mayence. All the affluents that the Vosges and Black Forest send down to the great river bend to the north as soon as

Fig. 137.—Middle Course of the Rhine.

they have emerged from their natal valley, and wind through the plain, tending in the same direction as the current of the Rhine. Above and below this wide plain of alluvium, in which nature has afforded no obstacle to the free passage of the water, the lateral rivers do not double round in this way before they join the Rhine. Being kept back by the mountains or hills which command them, they fall directly into the river, nearly at a right angle to it.

CHAPTER L.

PERIODICAL RISING OF STREAMS.—SNAGS AND FLOATING TREES.—ICE-FLOODS IN THE NORTHERN RIVERS.—INUNDATIONS.

A LARGE supply of rain-water being the principal cause of the swelling of rivers, the rainy seasons must necessarily be the times when floods are generally produced. In tropical regions, where the zones of clouds and showers shift regularly from north to south and from south to north during the course of the year, the fluctuations in river-levels can be calculated and predicted beforehand, like the seasons themselves, according to the passage of the sun over the ecliptic. When the luminary shines above the northern hemisphere, and dry seasons prevail on the north of the equator, the watercourses in the northern tropical zone become low, and many are completely dried up. During the winter season, on the contrary, when the sun has brought back to the north the rain-clouds and tempests, then the rivulets, streams, and rivers again swell and flow brimful of water. The same phenonema take place in a contrary order in the southern hemisphere. Thus the level of running waters on the north and on the south of the equator fluctuates in turn, so as to form a kind of annual tide, which in its regularity may be compared to the daily tides of the ocean. We must, however, add that in all tropical regions the periodicity of the annual floods is variously modified both by the relief of the ground and also by aerial eddies and other phenomena which have an influence on the rainfall.

Amongst all the rivers of the intertropical zone, the floods of the Nile have obtained the most world-wide celebrity. Herodotus and other Greek historians have described, with a sort of religious astonishment, this periodical swelling of the sacred river which conveys to Lower Egypt the soil which nourishes it. To the agriculturists by the river-side, this beneficent flood seemed like a miracle, and their priests never failed to take advantage of it so as to increase their power over the people. So long as the valleys of the Upper Nile and its tributaries were unknown, it was really difficult, when surveying the annual inundations of the river, not to consider it as a prodigy. The course of the Lower Nile is not fed by a single tributary; it traverses an arid country rarely watered by the rain of heaven; a burning sun evaporates its water, and yet, all of a sudden, about the beginning of July, the river-level rises, without any apparent cause, in its wide isle-studded bed. The water rises, and goes on rising, and from August to October it covers the sand-banks, flows over its brink, and, inundating the banks, pours itself out in strata no less regular than the annual rings in the trunks of trees. At the very highest flood the river often contains a mass of water twenty times

as great as that which it conveys to the sea when at its very lowest, and yet perhaps the Egyptian sky has not for several months yielded a single drop of rain. This prodigy, incomprehensible enough to our ancestors, may nowadays be easily explained. The enormous mass of water, which serves to irrigate the cultivated districts of the delta, proceeds from the snow and rain which the clouds so abundantly shed on the mountains of Ethiopia and on the other countries of equatorial Africa.

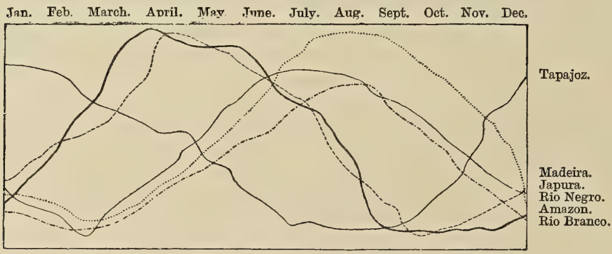
There are many watercourses in the intertropical zone which afford the phenomenon of periodical floods with as much regularity as those of the Nile; but there are none which are more curious in this respect than the great river of the Amazon basin. This "Father of Waters" flows nearly under the equator, and receives simultaneously the affluents of two hemispheres. Owing to this arrangement of its river system, the floods of the northern rivers take place in summer and autumn, whilst the southern tributaries overflow during the winter. The principal river and the Madeira are mostly swelled by the equinoxial rains, and their floods take place in spring and summer. An actual system of compensation is thus established in the lower bed of the Amazon between the tributaries flowing in on the right bank and those on the left. When the Pastaza, the Japura, and the Rio Negro are at low water, the Ucayali, the Madeira, and the Tapajoz are running brimful; when the latter begin to get low, the northern affluents increase their mass of water.

Beyond the tropical zone, rivers must necessarily manifest less regularity in their annual floods, the rains themselves being more irregularly distributed among the various seasons. Nevertheless, an unquestionable system of order never fails to show itself each year in the fall of atmospheric moisture, and this system is again met with in the corresponding fluctuation of the river-levels. This is a fact which may be proved by the study of various watercourses. In regions like the north of France, which are favoured with rains in winter, spring, and summer, the floods generally take place between the 15th of October and the 15th of May, and it is only due to the rapid evaporation which takes effect during the hot weather that summer floods are so very rare. In the Mediterranean districts, where autumn rains predominate, the watercourses begin to swell towards the end of the year. In those river-basins which, from the vastness of their area, extend into several meteorological regions, the fluctuations of level, which succeed one another with more or less regularity in each of the different affluents, are combined so as to form a fresh series of floods as regards the principal artery, and the general course of these floods may be easily foreseen. The most striking example which can be mentioned is that of the Mississippi, a river which unites in its vast bed the waters coming from the great western deserts and the streams flowing from the Alleghanies. At New Orleans the river commences to rise about the 1st of December, and its mass of water increases until about the middle of January, which is the time of the first flood. Then the level slowly sinks, and afterwards remains nearly stationary during the months of February and March. In April and May the river swells afresh, and in the course of the month of June it forms the great flood so dreaded by the planters. Immediately after it sinks rapidly until the end of September, and its lowest level coincides very generally with the commencement of November.

Several watercourses in the temperate zone exhibit, in the fluctuations of their level, a phenomenon of compensation similar to that of the Amazon. These are rivers which are replenished simultaneously by streams fed by rain-water, and also

by torrents increased by the melting of snow and glaciers. The variations of lowland streams being, as regards the seasons, precisely contrary to the variations to which mountain tributaries are subject, the level of the main river remains at a nearly regular height. The rain-water tributaries diminish in bulk at the very time when the affluents, which have come down from the glaciers, are increasing—that is to say, in summer; in winter and spring, on the contrary, the glaciers supply very little water, whilst the plains are inundated with rain, and their streams are filled to the brink. Thus the abundance of one affluent balances the poverty of another. As an instance of this, the Rhone and the Saone have often been referred to. During the heat of summer the latter brings down only one-fifth of its winter discharge. On the other hand, the Upper Rhone rises much higher during the same season; but below its junction with the Saone the average height of its water is nearly the same during every season of the year. A compensation of a similar kind likewise takes place between streams of surface-water and those which are fed by springs. The rivulets which traverse the subterranean passages of rocks, cannot

Fig. 138.—Compensation of Floods in the Basin of the Amazon.



descend into the plain so rapidly as the watercourses which flow on the surface of the ground.

The grandeur of the geological operations accomplished by flood-waters are best to be appreciated on the banks of rivers which have been placed by the labour of man in a state of defence against the watery enemy. When the river Amazon overflows, it forms in some places, with the marshes on its banks, a perfect sea of 100 or even 200 miles in width. The animals seek a refuge in the tree-tops, and the Indians who live by the sides of the river make a kind of encampment on rafts. About the 8th of July, when the river begins to sink, the water, returning to its original bed, undermines the thoroughly soaked banks and slowly washes them away. A sudden fall then takes place, and masses of earth, amounting to hundreds or thousands of cubic yards in bulk, sink down into the water, carrying with them the trees and animals existing upon them. The very islands are exposed to sudden destruction; when the entangled masses of fallen trees, which serve as a breakwater to them, give way before the violence of the current, a few hours, or even a few minutes, are quite sufficient for their disappearance; they are literally washed away by the flood. They may be observed visibly melting away; and the Indians, who are quietly at work upon them collecting turtle-eggs or drying the produce of their fisheries, are suddenly compelled to fly for their lives. Then it is that the current of the stream is encumbered with long floating piles of entangled trees, which hitch together only to break away again, and accumulating round some headland, are

heaped up one above another all along the banks. All round these immense trains of trees, which roll and plunge heavily under the impetus of the current like great marine monsters or drifting wrecks, great masses of the plant *Canna rana*, float on the surface of the water, giving to some parts of it a resemblance to broad meadows. We may thus readily comprehend the almost religious awe which has been experienced by travellers who have made their way up the river of the Amazons, and viewing these whirlpools yellow with sand, have been eye-witnesses of their destructive operation in tearing away the river-banks, throwing down trees, washing away islands in one place to form them again in another, and drifting down the current long trains of trunks and branches. "The great river was terrible to look on," says Herndon, the American traveller, "as it rolled through the solitudes with a solemn and majestic air. Its waters seemed to wear a wrathful, malevolent, and pitiless aspect. The entire landscape had the effect of stirring up in the mind a feeling of horror and dread similar to that produced by the imposing solemnities of a funeral at sea, by the minute-gun firing at intervals, the howling of the tempest, and the wild uproar of the waves, when the crew assemble on the deck to bury their dead in the bosom of a troubled sea."

The Mississippi presents a remarkable instance of a great watercourse which man has recently annexed to his domain, and has succeeded in modifying considerably, as regards its geological action, during the course of a few years. In 1782, and even at the time of the great inundation of 1828, the whole of the region embraced between the left bank of the Mississippi and the course of the Yazoo—that is, an area of more than 30 miles in width on the average—was completely covered with water, as is proved by the bones of wild animals which have subsequently been found on the artificial mounds raised by the red-skin Indians. At the present day the river is confined on both sides by lateral embankments, and no longer floods the whole basin of the Yazoo. Now it only tears away narrow strips of the vast forests by the river-side; and even in the very highest floods the masses of trees which drift down the current do not form, as before, long floating trains.

Even at the beginning of the present century, these floating trains, or *embarras*, rendered the navigation almost impossible in some reaches of the Mississippi and its tributaries. A great portion of the courses of the Achafalaya and the Wachita were completely choked up by heaps of trees. In many places a person might cross them without any idea that he was going over a river. Bushes, and even large trees, grew upon some of these floating masses. One of these entanglements of drift-wood, known by the Americans under the name of the "Great Raft," always obstructs the bed of the Red River. This immense agglomeration of trees, under which the water disappears in a mass as if under a movable arch, gradually gets higher up the course of the river as the trees at the lower end break away, and the annual floods bring down fresh drift-wood to the upper extremity. The obstruction was probably first formed at the confluence of the Red River and the Mississippi, and has since gradually advanced 391 miles from the mouth, gaining a mile or two every year. In 1833 the Federal Government undertook some important operations for the removal of the obstruction, which had then attained a length of 124 miles; but whilst a flotilla of boats was occupied in pulling out the snags which formed the lower extremity of the "raft," the upper end was constantly increasing by means of the fresh drift. In 1855, after twenty-two years devoted to this "labour of Sisyphus," the question was raised whether it would not be better to abandon this ungrateful labour, and to apply the funds at disposal

to the improvement of the *bayous*, or lateral channels. "The Great Raft" being thus abandoned in the marshes which formed the old bed of the river, will be gradually converted into a great peat-bed, destined perhaps to become coal at some future geological period, unless human ingenuity should otherwise dispose of it.

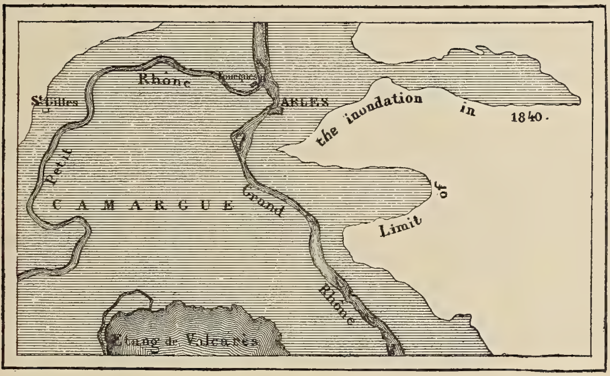
In cold countries, such as British America, Russia, or Siberia, the watercourses carry down to the sea a far less quantity of vegetable *débris* than the rivers in tropical countries; but, to make up for it, they are loaded with enormous blocks of ice at the time of thaw, a period which often coincides with the highest floods. It is a wonderful sight, especially in rivers adorned with cataracts, like the Niagara, when the rocks of ice, dashing against one another, and breaking up in the midst of the watery columns, give one the idea of a cataclysm, in which lakes and continents are all being simultaneously swallowed up in the abyss. The icy sheet which extends over the surface is shattered with a sharp, grinding noise, and the broken fragments are caught by the current, and dashed violently against each other; their sharp angles are broken off in the collisions, and they are whirled round and round in long eddies. In the curves of the headlands, at the points of the islands and sandbanks, and also in those portions of the river where the icy barrier still remains firm, the broken masses gradually accumulate, and, mounting up one upon another, owing to the force of their impetus, butt against the banks like battering-rams, and thus often clear away an outlet into the plains for the flood-water. Sometimes they rear themselves up like dams, and drive back the body of the river up-stream again. For this reason, dikes, embankments, and other hydraulic ramparts, built along the course of a river subject to the annual breaking-up of the ice, must be constructed with the utmost solidity. Amongst other constructions of this kind, we may mention the enormous buttresses with which the piles are furnished to support the bridge of Montreal on the St. Lawrence, and the defensive ice-breakers built in the Vistula on the up-stream side of each pier of the bridge of Dirschau. At St. Petersburg the granite quays and the edifices they protect would be all carried away by the ice-flood, if at the same time violent tempests from the west were to drive the waves of the gulf into the mouth of the Neva.

In temperate Europe the breaking-up of the river-ice is attended by little or no danger; but the mere inundations are very much dreaded on account of the towns, villages, and richly-cultivated districts with which the banks are covered. The inhabitants on the banks of the Loire still recall to mind with horror the disasters which were caused by the great though exceptional floods which in one year only (1856) carried away roads and defensive embankments, causing damage to a most enormous amount. In the same year the calamity was scarcely less disastrous in the valley of the Rhone, which was covered in some places, especially the Camargue, by an inundation almost like one of the floods of the Amazon. The inhabitants of the banks of the rivers are now worse off in this respect than their ancestors. The extraordinary rains caused by atmospheric changes are not all they have to dread. They have now to look for greater irregularity in the action of the streams and still more sudden inundations, in consequence of so many of the marshes and pools being drained dry, and the mountain slopes being cleared of wood by the axe of the woodman, or laid bare by the feeding of the goats. They also have to fear the immediate effects of the drainage channels which pour down the rain-water so rapidly into the streams. Lastly, the surface-water is every year precipitated into the plains more and more suddenly on account of the increasing number of ditches, which are carefully kept up along the roads and paths, into

which the boundary trenches of the various properties all empty. On the other hand, the extension of cultivation on the edge of a river, without the application of drainage, enables the earth to absorb the water to a lower depth in the soil, and thus diminishes the height of the floods. This fact is proved by the example of the Lake of Aragua, in Venezuela. At the commencement of the century, when the greater part of the neighbouring plains were under cultivation, the level of its water was comparatively low; but during the War of Independence it gradually rose, owing to the devastation of the country by the contending armies, and the consequent return of the plains to their original condition of virgin forest. Latterly, fresh clearings have for the second time sunk the water of the lake.

Under the action of all the causes which so variously influence the fluviatile economy, some rivers, such as the Oder, since 1778, and the Elbe, since 1828, have diminished in volume, although it is certain, from the meteorological registers, that the amount of rain falling into their basins has not lessened. Other rivers, as the Rhone and the Loire, do not appear to have at all decreased in the quantity of their

Fig. 139.—Limits of the Inundation of the Rhone in 1840.



water; but, on the other hand, their inundations are much more dangerous than formerly. The Seine, which, according to the testimony of the Emperor Julian, poured through Paris, some fifteen hundred years ago, nearly the same quantity of water in every season of the year, shows, at the present time, a difference of about 33 feet between the high and low water levels. Some rivers indeed, such as the Garonne, appear to have been more formidable in days gone by than they now are. The highest inundation of the Garonne which is on record is that of April, 1770. At Castets, the point at which the tide stops, the flood-level attained a height of $42\frac{1}{2}$ feet above the low-water mark. This is $6\frac{1}{2}$ feet more than in the largest floods of the present century.

However this may be, some of these inundations assume such proportions that they become perfect cataclysms for all the river-side districts. The example of three little streams, the Doux, the Erieux, and the Ardèche, all three confined to the limits of a single department, may give an idea of the rapid swellings of these high floods. On the 10th of September, 1857, the three watercourses, which usually flow peaceably enough over their rocky and pebbly beds, poured down into

the Rhone a combined mass of more than 18,000 cubic yards of water, instead of the 20 to 25 yards which was their ordinary discharge in the same time. This flood was equivalent to the body of water which the Euphrates and Ganges together pour into the sea. Spreading over their respective valleys to a height of 50 to 60 feet above their low-water mark, the flooded rivers overthrew the houses, washed away the cultivated ground, and uprooted the trees. So many thousand trunks of trees were carried away in one day that, below the Erieux and the Doux, the whole surface of the Rhone seemed nothing but a train of drift-wood, over which, as it appeared, a bold man might well have ventured to cross the river. Still, even these inundations have been exceeded, for, on the 9th of October, 1837, the Ardèche rose, at the bridge of Gournier, to a height of 70 feet above low-water mark, at least 10 feet higher than in 1857. Above the Iron Gates some of the floods of the Danube have caused the river to swell to a height of more than 60 feet above low-water mark.

It is a fortunate thing that, in most river-basins, it is very seldom the case that the floods of the various affluents exactly coincide, and that all the tributaries are seen to swell at the same time. In fact, whenever a rain-cloud passes through a valley, it discharges its moisture sometimes on one side and sometimes on the other, and the various watercourses which it swells overflow in turn after the rain-cloud has passed over. Thus, in the valley of the Rhone, when the damp winds encounter the Cevennes, the slopes of the Alps which are turned towards the river are sheltered from the storm, and it is only gradually that the series of showers makes its way from the Cevennes towards the mountains of Annonay. If all the tributaries of the Rhone were to swell at one time, it would roll down a most formidable mass of water, amounting to more than 130,000 cubic yards a second. It would be another Amazon. Even when the Rhone discharges into the sea only 16,000 to 20,000 cubic yards a second, the havoc which it makes upon its banks is most frightful.

CHAPTER LI.

MEANS OF PREVENTING FLOODS.—NATURAL AND ARTIFICIAL RESERVOIRS.—IRRIGATION CHANNELS.—EMBANKMENTS, AND CRACKS IN THEM.

IT is evident that it would not do for man to remain constantly under the apprehension of these inundations, and that it was necessary to find some means of preventing them. For hundreds and thousands of years, and especially during this century of industrial activity, numerous plans of protection against river-floods have been both projected and put into execution; but too often these works have remained useless, or have even produced entirely contrary effects to those which were expected by the engineers and the inhabitants. The fact is, that in these operations, sufficient attention is not always paid to the laws of hydrology. If man wishes to become master of the forces of nature, and to make them work to his advantage, the first condition is that he shall thoroughly understand them.

It must be remarked, in the first place, that the mass of surplus water forming a flood is not actuated with the same speed over all its width. The nearer the liquid particles are to the bank, the slower they move. This phenomenon, caused by the friction of the fluid against its banks and the bottom of its bed, may, it is true, be observed to some extent at low-water seasons as well; but it is when the level of the river is at the highest that the various portions of the liquid mass present the greatest differences in speed. The *thread of the current*, the mathematical line of the greatest rapidity, which varies every day and in every stream, according to the quantity of water, and the section of its bed, exceeds by about a fifth the average speed of the river. In flood-times this line gradually rises above the bottom, and by thus ascending towards the surface of the river, so as to keep—according to the direction or forces of the wind—sometimes on the surface of the river, sometimes a few feet below, it leaves the solid walls which constitute the sides of the river, and the medial part of the water, of which it is the ideal axis, and moves consequently with greater facility. In great rivers, such as the Amazon, the Mississippi, or the Rhone, the current sometimes descends with the speed of seven or eight miles an hour. Whilst the central part of the current thus hastens down towards the sea, the water at the side, kept back by the irregularity of the bed, remains behind, and flows more slowly along the banks. Thanks to this difference in speed, which increases according to the height of the river, floods are sometimes lessened or even entirely prevented. In fact, when mighty masses of water, descending either from the clouds or the mountains, fall simultaneously into the basin of a stream, these liquid avalanches would certainly produce formidable inundations if they were not immediately carried away by the centre of the current,

and did not distribute in succession a portion of their bulk over all the points that they traverse. Forming, so to speak, a river in the middle of a river, this rapid flow weakens the flood by dividing it over a vast length of bank. In the Ohio River the mid-flow has rolled down for a distance of five miles, when, at a spot two miles and a half from the very place where the rain fell, the high banks are scarcely touched by the rising water.

In consequence of the speed communicated to the mid-flow of the flood, the liquid mass that it carries along is perceptibly higher than the mean level of the river. It forms a kind of convexity, from the top of which the water spreads out in light sheets towards the two banks; but, on the other hand, when the flood-wave has disappeared, the middle of the river exhibits a considerable depression, and the water which has gradually accumulated near the two edges has to flow back towards the centre of the current so as to re-establish by degrees the fluviatile level. It has been ascertained that on the Mississippi the central convexity of the flood-wave is on the average about three feet. When the river sinks, almost as great an alteration of the level takes place in a contrary direction. The wood-cutters of Maine and Canada are not ignorant of this hydrological fact. They are well aware that logs of timber thrown into the river in flood-time are thrown up on

Fig. 140.—High-water Curvature.

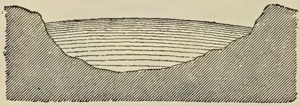
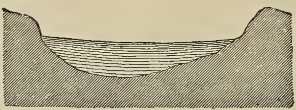


Fig. 141.—Low-water Curvature.



the banks, whilst they float regularly down the middle of the current when the river-level sinks.

The depression which is formed in the middle of the river during the period of subsidence is, however, obliterated as soon as the liquid masses cease to diminish; the water then commences to bulge up again in the axis of the current, owing to the greater facility of movement possessed by it in that part. The surface of those great Russian rivers which are covered with ice for several months of the year, exhibits a remarkable instance of the bulging up of the liquid mass in the central line of the current. At the conclusion of the winter, when the water from the melting snow runs down off the banks towards the bed of the river, and the sheet of ice stretched over the river is not yet broken, it is ascertained that the surface-water collects in elongated pools on those portions of the field of ice which are nearest to the edges, whilst the medial part bulges up in an arch above the current, and remains constantly dry. On the Volga, the difference of the level between the edges and the middle of the ice amounts sometimes to more than three feet.

The current is not the only regulating force which weakens the action of floods, and gives more certainty to the height of the water. There are other agents which assist in equalising the discharge of a river by receiving the overflow during the rainy seasons, and afterwards emptying it into the principal current. These regulating agents are the surface or underground reservoirs which exist on each side of watercourses which are still left in a state of nature. Thus, according to Humboldt, the Upper Maranon pours into the caverns of the *pongo* of Manseriche a portion of its waters, and also all the drift-wood which it

brings down from the higher valleys. Many streams lose a considerable quantity of water by the mere process of filtration through the spongy soil of their valleys. It is stated that in some places the water of the Nile penetrates laterally as far as fifty miles from the bed of the river. In like manner, during floods, the Seine feeds the land-springs which extend under Paris, and all the wells are then filled by the water of the river.

Next to lakes, which are the chief regulators of running waters, the marshes lying close to the edges of a river take the principal share in modifying its discharge. During inundations the lagoons and swamps on both sides temporarily store up a large quantity of flood-water, which is only set free after the sinking of the river. The marshy regions through which the Mississippi runs in its middle course afford a remarkable instance of this fact. Thus, in 1858, the great American river which, below the mouth of the Ohio, sent down 52,039 cubic yards of water, only discharged 45,915 yards at Bâton-Rouge, after it had received the contents of the Arkansas, the Yazoo, and other less important rivers. A mass of water, amounting to 6,124 cubic yards a second—equivalent to nineteen times the bulk of the Seine—must, therefore, have been lost on the way. Just in the same way, the Rhone, in its great inundations, makes its way over the side embankments opposite Culoz, and, covering the whole of the vast marsh of the Chautagna, pours its surplus waters into the Lake of Bourget. It has been calculated that during the flood of 1863 this reservoir absorbed from the Rhone a mass which altogether amounted to 71,900,000 cubic yards of water, the effects of which would have been most disastrous on the plains below.

In places where the riverain marshes have been drained by the operations of man, the water-level of the stream rises to a much more considerable height in flood-time, and the plains around are inundated. But the inundations themselves become new regulators of the discharge of the water, and that, indeed, by means of their very irregularity. The liquid sheet which covers the fields is hindered in its flow by the inequalities of the ground and by clumps of trees. Being unable to follow the river in its impetuous course, it remains behind, like a temporary lake, until the river is low enough for it to return into its natural bed. Thus the flow of an inundation always decreases in height as it gets nearer to the sea, and ultimately it completely disappears. The inundation of the Nile diminishes as it flows on from Assuan, where it is from 53 to 56 feet in height, to Rosetta and Damietta, where it is not more than 3 feet in height. A similar decrease in the flood-wave may be observed on all other rivers. We must not, however, lose sight of the fact that this gradual waste of the water proceeds partly from several other causes, such as the porous nature of the ground bathed by the river, the activity of the vegetation growing by its side, and the amount of evaporation. This last cause of the exhaustion of the water is probably the most important in all hot countries like Egypt and Guinea.

It should be man's part to complete the work of nature by imitating in his operations some of those means which she employs for storing up surplus waters, and afterwards distributing them equally over vast areas, thus insuring a regular discharge. Man should make it his task to watch the drop of rain as it falls from the sky, to follow it in its course, to arrest it in its progress when it would help to swell a dreaded flood, and to employ it for the benefit of agriculture, navigation, and manufactures. On every mountain-side and elevated plateau he may avail himself of a powerful remedy for the prevention of floods, by replanting them with trees; for, as M. Becquerel's experiments have proved, the quantity of water which drops

during heavy rain on wooded ground is only six-tenths of that which falls on the bare soil. In a great number of the upper valleys reservoirs might be constructed, where the liquid mass would accumulate in times of rain, and be subsequently emptied over the slopes in innumerable irrigating conduits. On cultivated declivities, as Provence and the Maritime Alps, man should enlarge and consolidate the flat stages which rise one above another along the mountain-sides, forming, as it were, so many staircases, each step of which should keep back its share of rain-water. In the valleys he should tap the river in order to feed irrigation ditches and mill-streams. Finally, in the lowland plains, it would be easy to line each side of the river with reservoirs, where the stream might deposit the sediment with which it is charged.

The streams, along which water-mills and manufactories have been established, are, as it were, controlled by means of the waste-water channels and by the reservoirs where the water is stored up, and especially through the mill-dams and other obstacles which convert the river or stream into a regular canal, with its dammed-up levels. Inundations are therefore very rare, or even quite unknown, in a great number of the manufacturing valleys of England, Scotland, and the United States. Still, the gratuitious power afforded by water is not by any means generally utilised at present; and even the inhabitants of manufacturing countries allow a very considerable quantity of available water-power to run waste. Thus—to select an instance among the French streams which turn the greatest number of mill-wheels—the Doubs itself, flowing through the manufacturing districts *par excellence,* scarcely does one quarter of the work which might be obtained from it. From Vougeaucourt to Besançon, a distance of 43 miles, the total fall being 248 feet, only 900,000 horse-power was utilised in 1850, out of the total amount of 3,400,000 horse-power which might have been employed.

Although manufacturing operations can only assist exceptionally in moderating and gradually doing away with floods, the agricultural processes which are going on in all the valleys inhabited by man ought to exercise a direct and decisive influence in regulating the flow of streams and rivulets. The husbandman ought not to allow the waste of a single drop of the beneficent water, which by a widely-extended system of irrigation might double, or even increase tenfold, his crops, and convert a wilderness into a garden. In the intelligent employment of running water in the fertilisation of a district, our agriculturists have much to learn from the example of the ancients. As far back as the time of the early Egyptians, works of irrigation of really colossal dimensions had been accomplished; and, perhaps, among all the undertakings of this kind due to modern industry, there is not one which, in boldness of plan or practical utility, can be said to surpass the *meri* (basin), or Lake Mœris, which was opened to the waters of the Nile in the reign of Pharaoh Amenemha III., more than 4,500 years ago, according to the chronology of M. Brugsch.

From the topographical details which have been left by ancient authors as to this wonder of the world, we know that the site of Lake Mœris must be looked for in the present province of Fayum, the name of which is derived from the Coptic, and signifies *sea.* Now, a considerable lake exists at the present time—the Birket el Kerun—in the lowest part of the province; and so long as the geography of this part of Egypt was but partially known, it was very natural to look upon this lake as the ancient excavation of the Pharaohs. A study of the localities has proved that this is not the case. In fact, the Birket el Kerun is situated in a deep depression, nearly on a level with the sea, and 53 feet below the average waters of

the Nile. This basin, therefore, cannot be the one which alternately received the surplus flood-water of the river and emptied it out again through two wide gates, as Strabo tells us, into the plains by the side of the Nile. Besides, the position of this lake differs much from that which the ancient geographers assigned to the Mœris. According to the discoveries of M. Linant de Bellefonds, the engineer, the site of the great reservoir was just in the very highest part of Fayum, to the west of the rocky gorge of Illaoun, through which flows a natural side-channel of the Bahr Yusef, which probably, at some former geological period, was the principal current of the Nile. Fragments of a long dike, which in some places is not less than 30 feet high and 200 feet wide, may still be met with in the eastern part of Fayum. It must once have constituted a semicircular rampart, spreading round

Fig. 142.—Map of the Fayum.

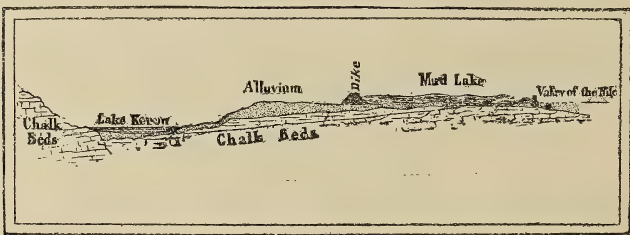
the outlet of the great basin of the Fayum plains, and have penned back the water brought by the Bahr Yusef.

M. Linant has calculated that, during the hundred days of flood, this branch of the river, which represents on an average about the twenty-eighth part of the Nile, emptied into the basin a quantity of water equal to 466 cubic yards a second, and that the total mass of water contained in this gigantic reservoir, even after making allowance for evaporation, could not have been less than 3,694,000,000 cubic yards. This was sufficient to diminish very considerably the dangers resulting from the inundations of the Nile, and subsequently to afford all the water that was requisite for the irrigation of 444,000 acres. According to the statement of Herodotus, the surplus waters spread out to the west towards the Syrtes of Libya; that is to say, after crossing the lake, which is called Birket el Kerun, it filled the bed of a channel now dried up, which carried the waters of the Nile into the western deserts. At the present day, the Fayum still possesses a magnificent system of irrigation, which may be compared to the ramifications of the arteries and blood-vessels of a living being: but forty-five centuries ago, Lake Mœris, which constantly changed its level according to the needs of agriculture,

was like a heart from which the flow of life was shed out to nourish the great body of Egypt as far as distant Memphis. Nothing now remains of Mœris but the broken-down dikes, a few fragments of the two pyramids which were built up in its waters to the glory of Amenemha, and a thick layer of alluvium deposited on its basis by the troubled waters of the Bahr Yusef.

Among European rivers, the Po is that which may be best compared to the Nile of the ancients, as regards the care with which its waters have been utilised for the fertilisation of the soil. So far back as 1863, the Lombard agriculturists required for the watering of their crops 59,000,000 of cubic yards of water a day, equal to 681 yards a second; that is a liquid mass equivalent to the average discharge of the Seine during the same period. Since the above date, the great Cavour Canal has been opened—a perfect artificial river—which requires for itself alone 144 cubic yards of water a second. Starting from Chivasso, below Turin, this river, which is not less than 55 yards wide at its commencement, spreads its fertilising water on both sides in the already fertile plains of Lomellina; it receives, *en route*, numerous streams—the Elvo, the Sesia, the Agogna, the Terdoppio—and at Turbigo empties into the Tesino all that remains of its liquid mass after having irrigated more than 494,000 acres. Next to the great canal of the

Fig. 143.—Section across the Fayum.

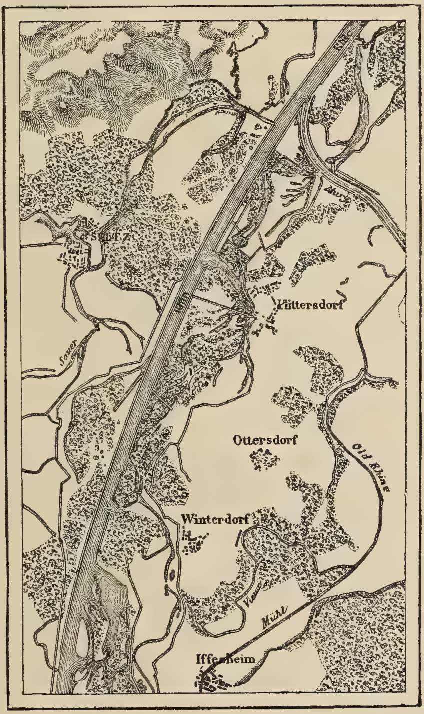


Ganges, in Hindustan, it is the most important operation of this kind accomplished in modern times. There can be no doubt that the Po, once so dreaded on account of its sudden floods, will ultimately become, in conjunction with the other watercourses of Lombardy, a scientifically arranged system of agricultural canals.

Agriculturists should not only employ the water of torrents and streams for increasing their crops and nourishing the soil, but they should also make use of the sediment and *débris* of all kinds, which are washed down from the upper reaches. As an instance, let us take the Durance, a French river, which had been thoroughly surveyed and studied to ascertain the plan for utilising its water and mud for the irrigation and manuring of the plains by the river-side. The eighteen channels, which are fed by this stream, can draw from it as much as 90 cubic yards a second; so that at any time when the whole of this liquid mass is being taken away at once, only 30 cubic yards remain in the bed of the Durance in low-water seasons, or about a quarter of its regular discharge. According to the observations of M. Hervé-Mangon, which lasted from the 1st of November, 1859, to the 31st of October, 1860, the mass of mud brought down by the stream during the whole year represents a quantity of near 18,000,000 tons. Some idea may be formed of the enormous bulk of the mud which is washed away every year by the Durance from the upper portion of its basin, by

picturing this mass in the form of a cube 242 yards on each side; if spread out uniformly on the ground this alluvium would cover in a year more than 108,000 acres with a layer an inch thick, containing in a form of combination most suitable to the plants more azote than 100,000 tons of guano, and more carbon than 121,000 acres of forests (?). Unfortunately, as these canals are constructed with a view to irrigation only, nine-tenths of the mud is lost for manuring purposes; and the farmers purchase, at the cost of many thousand pounds a year, the very

Fig. 144.—Dikes along the Rhine near Seltz.

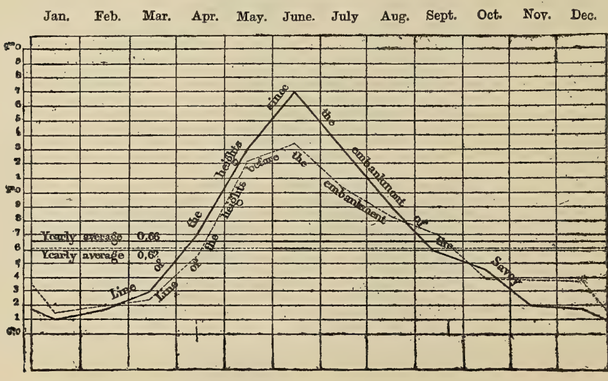


elements of fertilisation which their stream washes down into the Mediterranean, although they might so easily avail themselves of them.

As every river possesses its own special peculiarities, the regulating work, which the engineers have to undertake for the purpose of doing away with floods and distributing the water discharge, must be contrived in different ways, according to the form and capacity of the upper mountain hollows, the rapidity of the current, the suddenness of the floods, the porosity of the ground by the river-sides, and the extent of the forests which clothe the hill-sides. The operation of regulating the discharge of a watercourse is certainly very difficult to accomplish; in some river-basins it would require the labour of several generations; but suffice it

to say, it is not impossible, and that it has already been successfully carried out in many parts of the globe. Although the greater part of the rivers, in both Europe and the civilized portion of America, have up to the present time remained free from man's guidance, and still occasionally devastate the cities and cultivated districts which lie along their banks, there are at least a few of which the floods have been rendered harmless, thanks to the labour of the frightened inhabitants. Among the rivers which were once most dangerous, and are now almost entirely subdued, we may mention the Arno, which has been looked after for centuries by the skilful Tuscan engineers. At one time this river was most formidable, on account of its periodical inundations. From the year 1400 to 1761, no less than thirty-one disasters of this kind are recorded. Since 1761—the date when the improvements of the river were carried out—until 1835, there has not been a single serious flood. The Po itself—the river which in flood-time hangs suspended, so to speak, over the surrounding plains—is now much less to be dreaded than

Fig. 145.—Mean Heights of the Isere.

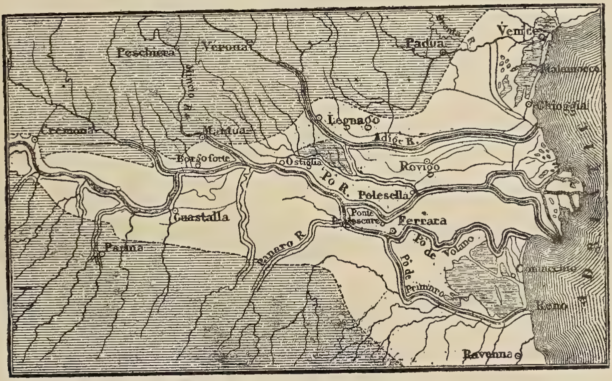


heretofore, thanks to the irrigating channels which tap it, and also to the lateral embankments which border the whole of its lower course below Cremona.

In this stream, as in a great many others, the surplus waters of the high floods come down too rapidly, and in masses too considerable, to afford any possibility of storing them up, or of turning them off in a lateral direction, without devastating the plains. It is necessary that the inhabitants should protect themselves by well-planned constructions against the threatening pressure of the water. The Egyptians dwelling in the delta built their cities on artificial hillocks above the level of the annual floods. The inhabitants of some parts of Holland, wishing to facilitate the "warping" of the fields, elevate their habitations above the ground, and the houses become so many islands in the midst of the floods. In recently colonised countries, where man's first care is to protect his habitation, all he does at first is to construct a circular embankment round the town or village. This was the procedure of the French colonists, after they had planted the first pile-work of New Orleans. The Americans, too, adopted this plan of protection for the Californian city, Sacramento, and for the warehouses at Cairo, situated at the confluence of the Ohio and the Mississippi. In like manner, the towns on the

banks of the Loire are protected against the flood-wave by walls. Added to this, when the banks of a watercourse are covered by cultivated fields, and the inundation would prove fatal to them—as in Louisiana, Lombardy, China, and many other countries in the temperate zone—it is necessary to raise longitudinal dikes on the edges of the streams which at flood-time are higher in their level than the surrounding plains. Thus shut in between their dikes, rivers are compelled to give up their wandering course, and to flow down to the sea through the channel which has been traced out for them. These longitudinal embankments, which, at any rate, are no ornament to nature, are sometimes a matter of absolute necessity; but if the constructors wish to prevent their dikes being broken through, and to avert the disasters which are the certain consequence of cracks, they must calculate beforehand the force of the liquid mass with which they will have to contend during extraordinary floods; and they must build their ramparts of materials sufficiently solid to resist without difficulty the lateral pressure of the water. They must likewise carefully protect their dikes against burrowing

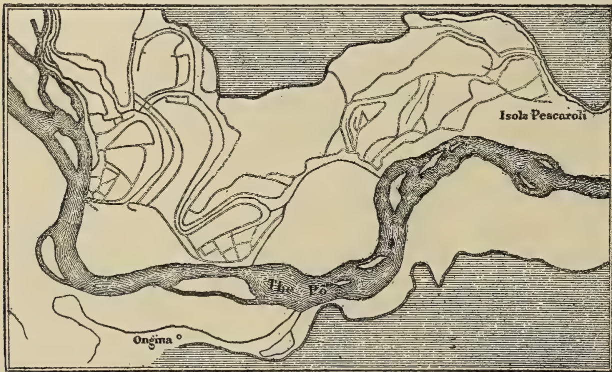
Fig. 146.—Dikes by the Po, from Cremona to the Sea.



animals, for the embankments of the Po have several times been perforated by moles, and those of the Mississippi by musk-rats. It is necessary, also, to give the embankments a gentle bend, and to leave a sufficient width for the penned-in river. The Loire, in front of Orleans, was once 3,827 yards wide, but has been reduced by the embankments to a bed of 306 yards. At Jargeau, it is only 273 yards wide at a place where it once had a lateral spread of 7,650 yards. In 1856 the Loire forced twenty-three breaches through these banks, which were said to be impenetrable; as soon as the height of the flood rose in the river to more than 16½ feet, cracks became inevitable. The losses occasioned by the breaking down of these too feeble ramparts, over which the flood-water rushed like a deluge, were so considerable that the question was often asked whether it would not be better to throw the dikes down entirely and to replace them with plantations of trees. The water, flowing without difficulty through the open barrier of the crowded trunks, would be distributed equally over the plains by the river-side; and would consequently never rise to the formidable height which it reached between the dikes. Added to this, its annual ravages would be in great part compensated

for by the fertile alluvium which would be deposited by the sediment with which the water is charged. It has been calculated that if the vast basin of the Saone, situated above the gorge of Pierre-Encise, were protected against the inundations of the river by means of dikes, confining the water to a bed 273 yards wide, the same as at Lyons, a liquid mass of 1,869,000,000 cubic yards, which, during inundations like those of 1840, now spreads over the plains, would then rush down upon the town in the space of a few days. On the other side of Lyons the Rhone affords a remarkable instance of the influence which the dimensions of the bed exercise on the height of the flood. In 1856, in the wide plain of Miribel, 7½ miles above Lyons, the flood-water rose only 9½ feet; but it rose to 20 feet—that is, more than double—in the narrow bed contained between Lyons and the Brotteaux. In the valley of the Isere, the mean heights of the flood-waters have undoubtedly risen since the construction of the side embankments, which were, in fact, placed

Fig. 141.—Golenas by the Po.

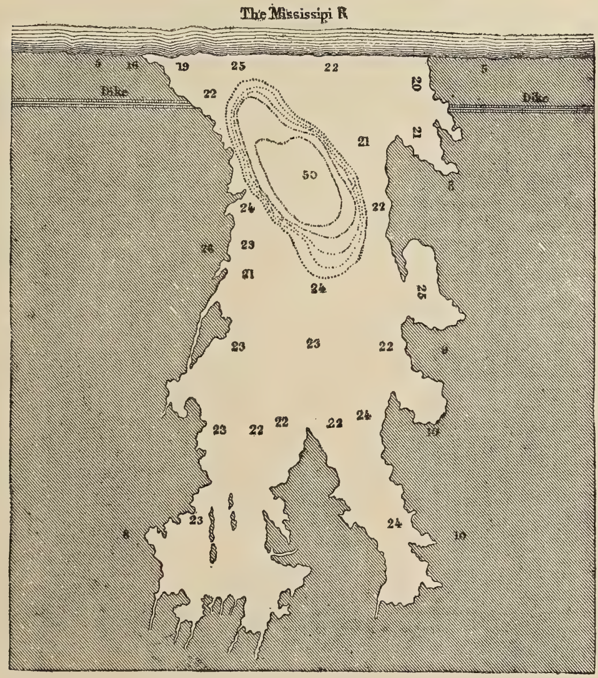


too close to one another. This has been proved by the very exact observations of M. Dausse.

The embankments of the Po, more scientifically constructed than those of the Isere, were commenced many centuries ago, when the long night of the Middle Ages still darkened the rest of Europe. At a point below Cremona, where the continuous line of dikes commences, they are very wide apart, but the space through which the flood-waters can flow is gradually contracted down to the mouth of the river; from 6,564 yards it diminishes to 3,000, 2,000, and even 1,000 yards. Ultimately each of the branches of the delta is not more than 300 to 500 yards wide between the enclosing embankments. The fact is, that a great portion of the mass of water, finding between its upper dikes so considerable a space over which it is able to spread freely, remains stored in the plains above, and thus the flood-water tends constantly to diminish in a down-stream direction. The flat districts that lie between the dikes are called *golenas*. Each landholder may cultivate them and embank them as he likes, but on the condition that his dikes shall be always nearly six feet lower than the principal embankments, so as not to offer any serious obstacles to high inundations. These *golenas*, therefore, with their dikes all round them, form so many settling reservoirs where the alluvium accumulates after each

fresh flood, and their level is much higher than the plains outside the dikes. Owing to the care with which these embankments are kept up by the syndicate of the riverside proprietors, cracks in them are very rare. Since 1705, the date at which a breach of more than 50 miles took place below Cremona, the reconstructed portion of this enormous rampart has not yielded at any point. Although lower down the river extraordinary inundations still occasionally break through the lateral embankments in some few places, any great disaster is in a measure prevented by the side channels, opened on both sides of the river, in the delta of the Po. Nevertheless, the system is not yet perfect. M. Lombardini thinks it very

Fig. 148.—Gap formed near New Orleans.



important that in the lower part of the river a considerable space should be left open to the flood-waters, so that the alluvium might be distributed on the plains on each side, instead of throwing out a promontory into the Adriatic Sea, and consequently raising the bed of the river.

Next to the embankments on the Dutch rivers, those of the Po form the most remarkable system of protection against inundations that has been devised in Europe; but they are inferior in importance to the embankments which run along a great portion of the Mississippi, and which, from their enormous size and length, from a source of admiration to every traveller. On the right bank of the river,

from Cape Girardeau (Missouri) to the Pointe-à-la-Hache, situated below New Orleans, the embankments form a wall of 1,125 miles in length, only interrupted by the mouths of rivers and a few spots of rising ground. On the left bank, the base of the plateau, which the Mississippi here and there touches, has enabled the inhabitants to dispense with the construction of continuous dikes; but they have been compelled to resort to embankments for protecting all the plains which extend from Memphis to Vicksburg, and from Bâton-Rouge to New Orleans. The ramparts that have been raised on the eastern bank are altogether more than 625 miles in length, and some of them are of very considerable dimensions; that which has

Fig. 149.—Shifting Beds of the Hoang-ho.

Scale 1 : 9,750,000.

Old course of the Hoang-ho. Course of the Hoang-ho before 1851.

0 45 90 135 180 Miles.

been constructed at Yazoo-gate, in order to close a *bayou* of the Mississippi, is no less than 42 feet in height, 42 feet in width at the top, and 317 feet broad at the base. To these immense constructions we must add all the embankments formed along the tributaries of the Mississippi and the *bayous* of its delta; we must likewise take account of all the double and triple parallel dikes which have been raised in some of the spots which are most exposed to the action of the river. The whole of the embankments of the Mississippi must altogether reach a total length of at least 2,500 miles. It is true that in many of these imposing ramparts there is still much to be wished for in respect to solidity. In 1868 the sum required to

thoroughly repair the embankments between the Ohio confluence and the gulf of Mexico was estimated at about £4,000,000. In 1882 the most disastrous floods ever witnessed in the United States covered an extent of over 80,000 square miles, or more than a third of the whole of France. Yet the riverain populations have already nearly completed the work of reparation, a work which may be compared to the labour of Sisyphus.

Every great flood on the Mississippi which has been recorded has formed one or more breaches in the embankments above New Orleans. The water then rushes like a cataract into the plains which extend below its level to a depth of 10, 12, and even 15 feet. It rapidly enlarges the opening by washing down the dikes for an extent of one or more miles, and then digging deep into the soil, hollows out for itself a new bed across the plantations. One of these temporary beds, which the river made in 1850, 1859, and 1862, near the hamlet of Bonnet-Carré, discharged no less than 3,930 cubic yards of water a second; that is a sixth of the average liquid mass of the Mississippi. If the inhabitants had not succeeded in stopping it up on each occasion, the new river would, without doubt, have gradually become one of the branches of the delta of the Mississippi. In like manner the Hoang-Ho, having burst through its embankments, emptied itself into the sea, partly to the north and partly to the south of the peninsula of Shantoung, leaving a distance of 217 miles between its two mouths. The territory exposed to its ravages was not less in extent than the whole area of England. According to a tradition related by Ritter, which, however, is doubtless exaggerated, 200,000 individuals of the province of Honan were drowned during a civil war in consequence of the dikes being cut through.

CHAPTER LII.

THE MOUTHS OF RIVERS.—ESTUARIES.—LONG BANKS OF SAND.—DELTAS.—NETWORK OF BRANCHES OF RIVERS IN ALLUVIAL PLAINS.

BELOW its confluence with its last tributary, a river cannot fail to diminish in volume, on account of the evaporation of its water, and also of infiltration into the earth. There are, indeed, some streams which, as we have seen, gradually waste away without receiving any compensation from tributaries to make up for their liquid loss, and ultimately entirely dry up. Not only in the burning regions of the torrid zone, where rains are rare, but also in the great plains of the temperate zone, wherever the surface of the ground is too level to afford a sufficient incline, we find many rivers flowing down from the mountains, and then, failing to make their way to the ocean or any inland sea, they disappear among the sands of the level country. Thus the Rio Dulce, the rivers Primo, Segundo, Quinto, and several other watercourses in the Argentine Republic, come to an end amid the *pampas* in a series of lagoons, which rise or fall, advance or retire, in the desert, according to the seasons of the year or the quantity of water. Farther up-stream these rivers are navigable for boats, and sometimes flood the land far and wide. But below their current becomes weakened, they break up into pools, and at last, becoming little more than liquid mud, they fail even to moisten the soil of the prairie. In a similar way the branch of the delta of the Rhine, which retains the name of the river, disappeared amid the sandbanks previously to 1806, the date at which a canal was dug through the dunes, and was protected against the sea by efficient flood-gates.

A river, however, can scarcely be considered to be worthy of its name, and can play no important part in history, if it fails to send down its water to the ocean in a constant and regular way. Only under these conditions is it accessible to ships, and in a position to connect the inland districts with those of the sea-coast. Just as a tree, the trunk of which, formed by the union of all its branches, brings into communication the atmosphere and the bowels of the earth, so the chief *trunk* of the river, in which all its affluents combine their liquid mass, links the sea to the mountains and to the plains. By its ever-moving flow, by the junctions of its own current of fresh water with the salt waves of the rising tide, it brings together all parts of its basin, and gives life and energy to the earth, as the blood quickens the flesh which it moistens.

The oceanic portion of a river is characterised by the tides which twice every twenty-four hours change the direction of its current, and cause the water to flow back up-stream. In this small portion of its development, the action of a stream is

completely modified; it is no longer a watercourse, nor is it the ocean. It is, in fact, a common bed where the two elements meet and unite. The river-mouth is not only an entrance to a continent through which navigators may pass, it also opens an outlet to the sea-water, and enables it to ascend far inland, and to mingle with the liquid mass brought down by the river. That portion, therefore, of the channel where the junction takes place between the salt and fresh water constitutes a geographical division which is perfectly distinct from all the rest of the basin.

Most streams, however winding their course may have been, straighten as they approach the sea, and descend towards the shore by the shortest line possible, so as to form a right angle with the coast. This tendency may be partly explained by the fact that the steepest slope of the ground is generally inclined in this direction; but another cause, also, is the alternate action of the tide-wave, which takes place perpendicularly to the shore, the to-and-fro motion of which ultimately governs that of the river.

Added to this, a large number of rivers, when they reach the maritime portion of their course, spread out their banks very widely so as to form real gulfs, in which it would be impossible to trace out the precise limit which marks the river-mouth. When these inlets are not original indentations of the coast, they owe their existence to the combined action of the river and the sea, which gradually cuts away the banks, and ultimately deposits them on some distant shore. Thus, fluviatile estuaries are generally found on those parts of the coast which are directly exposed to the force of the tides and storms. Estuaries are very numerous on the coasts of the open sea where the tide rises to a great height; but they are comparatively less frequent in land-locked seas, which preserve an almost unaltered level, such as the Mediterranean, the Baltic, and the Caribbean Sea. Nevertheless, the shores of several inland seas—among others, the Euxine, so formidable for its winds—present river-estuaries similar to those on the oceanic coasts; the most remarkable are the *limans* of the Dniester and the Bug.

Almost all the rivers of Western Europe spread out into estuaries in the lower portion of their course. There are some among the number, as the Thames, the Severn, and other rivers of Great Britain, which are streams of no great importance above the gulfs at their outlets, and owe all their consequence to the powerful tide-waves of the Atlantic. In France, the Seine, the Loire, and the two combined rivers of the Garonne and the Dordogne, water basins which are better proportioned in their area to the dimensions of their estuaries; nevertheless, the quantity of fresh water sent down into these advanced bays of the ocean forms but a very small portion of the liquid mass which they contain. In the Gironde, which may be taken as a type of a marine estuary, the salt water generally ascends as far as Pauillac, 31 miles from the outlet; any one sailing on the river may readily notice the shifting line where the various liquid masses, some green and transparent, and others yellow and muddy, mingle with one another in long eddies.

At a point more than 10 miles from the sea-coast, the saltness of the Gironde is scarcely diminished by the admixture of fresh water. At one time, the low ground by the river-side was intersected by salt marshes, and the creek of Méchers, on the north bank, has been utilised for some years in the cultivation of oysters. The depth of the estuary is also very considerable. At Méchers, the Gironde, which at that place is $7\frac{1}{2}$ miles wide, is from 50 to 100 feet deep even at low tide. At the outlet properly so called, the estuary contracts, and is only $3\frac{1}{4}$ miles wide; but in mid-channel the sounding line finds no bottom at 100 feet.

This enormous basin does not look like a river. If a spectator contemplates it, not from the point of a headland, but merely from the edge of the shore, at St. George or Royan, he cannot distinguish the whole extent of the opposite bank: all that is visible is a few clumps of pines, separated by the white line of the distant water, and these isolated clumps seem to form an archipelago; the Gironde appears like a sea dotted over with isles and islets. The colour and the appearance of the water are continually changing; it is as if several rivers, crossing one another in every direction, were flowing in one and the same bed. Sandbanks which show their white masses indistinctly under the green waves, the marine currents which meet and mingle with the turbid water of the ebbing tide, and gusts of wind which raise on the estuary a perfect network of winding ripples, the long trains of foam which incessantly shift their place; lastly, the submarine counter-currents which flow up to the surface and there spread out in sheets perfectly smooth—all these ever-changing phenomena are always modifying the magnificent spectacle afforded by the Bay of Gironde.

But what, after all, is this beautiful estuary of the French coast when compared with the grand outlets of some of the American rivers, such as the St. Lawrence, the current of the Amazons, and the Rio de la Plata? This last estuary, into which pour the gigantic Parana and Uruguay, more than 6 miles in width, is at the outlet no less than 155 miles across, and occupies a space of more than 15,400 square miles. Within a recent geological period, it stretched over a still wider area. At that time, the Parana had not filled up with its alluvium all the higher portion of the estuary, and probably, also, the surface of the pampas was covered by the sea-water. Even in the present day, the now diminished gulf is nothing less than a real sea. Its bed, which prolongs in a gentle slope the surface of the Argentine plain, is hollowed out 66 to 100 feet below the level of the ocean. Currents and counter-currents, like those in the open sea, traverse the gulf in every direction. Furious winds, which seem to upheave the whole liquid mass, give rise to tempests which are more dreaded than those of the ocean, on account of the sandbanks and rocks which hem in the channels. The highest floods of the Uruguay and the Parana have no perceptible influence on the level of the Rio de la Plata, and seem lost like rivulets in the enormous estuary.

Although the winds and tide have such an effect in increasing the mouths of rivers, into which the waves enter in a direct line, their mode of action is very different when they are diffused along a sandy shore, which they meet at a very acute angle. In this case, the waves from the open sea, being driven obliquely against the coast, wash away from it large quantities of *débris*, which they deposit in front of the mouth of the adjacent river. Under the enormous pressure of the ocean, the current of the river bends and gradually doubles round in the same direction as the marine current, allowing a tongue of sand to form across its former bed. In the course of time, a narrow peninsula, having a sea-shore on one side and a river-bank on the other, divides the fresh water from the salt water for a distance of several miles, sometimes breaking up into islands, according to the various changes of the atmosphere, the current, and the tides. Thus, on the coast of New Grenada, extending from the Cape de la Vela to the foot of the snow-clad mountains of Santa Marta, all the river outlets are pushed towards the west by the current which runs along the shore towards the Gulf of Darien; mere embankments, ornamented here and there with green vine branches, and the violet corollas of a kind of bindweed protect the still waters against the onset of the breakers.

The River Senegal exhibits one of the most remarkable examples of these belts,

formed along the shore by the marine currents, and running across the outlet of a river. For a distance of more than 180 miles, the great watercourse follows a direction perpendicular to the coast. In this way it reaches a point 15 miles from the sea, at which its course is arrested by a chain of dunes, and it is compelled to find an outlet through some other part of the sea-shore. At one time, the river, or at least one of its branches, continued in its direct path to the ocean, and on the spot where its former bed may still be traced there is a narrow marshy flow, known under the name of the Marigot of N'diadier. Being thus driven in a south-westerly direction, the Senegal is compelled to approach the sea obliquely. Above St. Louis,

Fig. 150.—Belts of the Senegal.

the river is separated from the line of breakers by nothing but the narrow bank of the Guet-N'dar, on which the blacks have built their *faubourg*. Farther down the coast, the embankment of sand thrown up by the marine current running from the north continues for a considerable length, altering its position every year, owing to the double action of the river-floods and the sea-waves. At the present time, the mouth of the Senegal opens 2½ miles south of St. Louis, and is ascending slowly towards the town. In 1849 it was 9 miles farther to the south; but, in 1825, it was near Gandiole, a little farther up the stream. This sandy rampart, which extends its graceful curve from north to south for more than 24 miles, is cut through by the current of the river, sometimes at one spot and sometimes at

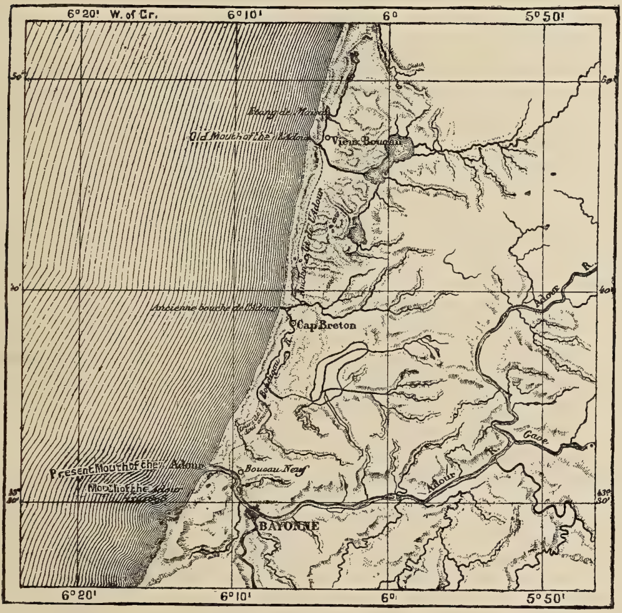
another; but it never fails to form again, owing to the action of the sea-waves. Until the operations of man have fixed the place of the mouth of the Senegal, it will continue to shift its position along the sandy dike.

In a similar way all the various streams which empty into the sea along the low coasts of the French *Landes* bend round towards the south as soon as they reach a point at a short distance from the sea-shore. There is, in fact, a current produced by the swell which runs parallel to the shore of the *Landes,* a matter which is easily proved by noticing the drifting of any floating substance, or the bearing of shipwrecked vessels, which always point their sterns to the south. This current pushes before it masses of sand, which are mixed with the breakers, and thrown up upon the beach. The sandy points, which are constantly augmented by the additions brought by the waves, are thus elongated towards the south, and would ultimately reach the bases of the Pyrenean promontories if it were not for the tendency of the streams to rise, so as to increase their slopes, and thus to press with increasing weight on the sands which obstruct them. Formerly the waste channels, or *courants,* of the Lakes of Soustons and St. Julian flowed parallel to the sea for a length of several miles above their outlet, and fears were entertained that, in consequence of the lengthening of these streams, and the rise in their level, the lakes above would spread over the surrounding country. In order to avert this disaster, the inhabitants undertook to rectify the course of the waste channels, and thus to lower the level of the lacustrine waters. This plan succeeded perfectly as regards the Soustons lake. Its level was sunk 10 feet, to the great advantage of the village near, which was enriched with a tract of fertile alluvium. The Lake of St. Julian was likewise lowered several feet by the alterations made in the *courant* of Contis; but the engineers met with considerable difficulty in mastering this watercourse, and in preventing it from flowing in a southerly direction parallel with the coast. They were several times compelled to lengthen the barrier which forced it to flow in a straight line down to the sea. As regards the more important stream of Mimizan, which serves as a waste-channel for several considerable lakes, an attempt was often made to dig out for it a regular bed in the direction of the coast, and to retain the flow of water in it; but the river would not be subdued, and, throwing down the barrier of piles and faggots which was opposed to it, continued to run towards the south and south-east. Miles of wicker-work dikes, which were set up to guide its waters, now lie buried under the dunes.

During the course of the Middle Ages, and probably also in the previous historical era, the Lower Adour—which is now perpendicular to the coast—extended in a line parallel to the chain of dunes and the sea-shore for a length of about 12½ miles. The river then fell into the sea at a short distance from the spot where the town of Cape Breton now stands. Towards the end of the fourteenth century a violent tempest obstructed this outlet, and the Adour, thrown back farther to the north, found no place of issue nearer than a point 22 miles from Bayonne; a village called Vieux Boucau (old mouth) marks the banks of the former river. At first sight it seems as if this ancient course of the Adour is to be explained in a similar way as the curves described towards the south by the streams of the *Landes;* but if this were the case, the current of the sea-swell in this part of the Bay of Biscay ought to tend in a *northerly* direction. Now the action of the waves points, on the contrary, from north to south, as far as the mouth of the Bidassoa, and consequently the sandy points are lengthened with a southerly bearing. The belt of banks across the course of the Adour was turned

towards the *north;* it is, therefore, necessary to look for the cause of this in the existence of a chain of dunes solidly based on the nearest Pyrenean rocks, which presented an insuperable barrier to the river on the western side. In 1578 this chain was broken through at a point three miles and three-quarters below Bayonne, by means of a trench cut by Louis de Foix, the engineer, and still more by a formidable flood, which threatened to carry away the city. Since this date, the mouth of the Adour, yielding to the coast-current, constantly tends to bend round towards the south; and on this side the piers formed to maintain the river are carried the farthest. At the end of the seventeenth century—at a date when these latter works had not been commenced—the river, bending gradually towards

Fig. 151.—Old Course of the Adour.



the south, emptied itself into the sea at the foot of the rocks of Chambre d'Amour, about two miles from Boucau-Neuf (new mouth). If the river had not been repelled on the right by the dikes constructed by Louis de Foix, it is very possible that it would again have turned towards the north.

One of the most wonderful phenomena on the face of the earth is the formation of those long banks of alluvium which affect a considerable number of streams, and, for a distance of hundreds of miles, protect a multitude of river outlets against the waves of the sea. A magnificent example of this formation exists on the coasts of Virginia and North Carolina. The rivers there, which flow on the surface of the ground, counterpoising the pressure of the ocean in the same way as the subterranean waters of Yucatan, have formed out at sea an immense breakwater. This

sandy dike, which is not less than 186 miles in length, bends round the continent in gracefully winding curves, and encloses within its limits perfect seas, with their bays, archipelagoes, and currents; behind this the Tar, the Alligator, the Neuse, and several rivers run into the sea. An idea may be formed of the peculiarities presented by these long banks, common to several rivers, by comparing this dike with the altogether regularly formed littoral bank which lies in front of the Cape Fear River, immediately to the south.

A third arrangement of the mouths of rivers is that which the ancient Greeks designated under the name of *delta* (Δ), on account of the triangular form so often assumed by the alluvial plain embraced between the branches of a river. This plain, which projects beyond the regular line of the coast, is nothing but a former estuary, which has gradually been filled up with mud and sediment of every kind. This alluvial plain cannot be formed to any great extent in places where the swell, the currents, and the tides are constantly disturbing the outlets of the rivers. It is necessary that the stream should be subject to conditions somewhat similar to those existing in still lakes, where deltas form without the least obstacle. These conditions are found in almost inland seas, with a scarcely perceptible current—such as the Mediterranean and the Baltic—which allow river-mouths to gradually fill up with mud. The alluvium which is brought down by the river is certainly soft, and has but little solidity; it is often roughly handled by the water at flood-times, and fails in preventing the liquid mass from forming forks, or even from dividing into numerous branches. But the sea, which assails these deposits, being constantly at about the same level, ultimately has the effect of consolidating them by dashing against them with its waves. On the contrary, when a river falls into a sea where the tides rise to a great height, and where the coast is alternately traversed by the rapid currents of the ebb and flow, no time is left for the deposit of the river alluvium. This matter is first pushed back into the river by the flow of the tide, and then, being seized by the ebb, is carried out to great depths in the open sea. In this contest between the river and the ocean, the latter gets the advantage on account of the enormous mass of its waves, which, by their fluctuating movement of rising and falling, are incessantly scouring out the estuary through which the fresh water flows.

Amongst those rivers the deltas of which are incessantly gaining on the sea, we may mention, as belonging to the first class in this respect, the great affluents of the Mediterranean—the Danube, the Nile, the Po, and the Rhone; also, in the Caspian, the Terek, the Kuban, and the Volga. Other rivers possessing deltas fall into the sea at the extremity of some gulf well sheltered by a barrier of isles, and visited only by scanty tides. Of this kind are the Hoang-ho, the Yang-tse-kiang, and other watercourses, the alluvial shores of which continue to project more and more into the shallow China Sea and the Pe-tchi-li Gulf. The delta of the Mississippi, which may serve as a type to all other formations of the same nature, pushes its way into an almost closed gulf, where the height of the regular tide never exceeds 3 feet. The only instance which can be mentioned of a great river-delta existing at the extremity of a gulf widely open to the ocean, is that of the Ganges and the Brahmaputra. But it must not be forgotten that at the outlets of these rivers, the tide fluctuating between 1 foot and 16½ feet, never exceeds, on the average, 10 feet in height; added to this, the delta, instead of pushing its way far into the sea, presents a flattened shape, and extends its low shores from east to west, giving a width of at least 186 miles. There is no doubt that in a more protracted sea, the delta of these two combined rivers of Hindustan,

which bring down in their turbid waters so large a quantity of alluvium, would have thrown out a long promontory of delta exhibiting very different proportions.

In a cursory and rapid examination of a map, it would, however, be easy to fall into error as to the real character of certain river-outlets, and to look upon them as actual deltas, thrown out by the action of the river itself, instead of collections of soil deposited under the shelter of isles of marine formation. Thus, Holland, which is placed at the angle of the continent of Europe, appears at first sight to be the combined delta of the Scheldt, the Meuse, and the Rhine; but the outer shore is, in fact, an ancient coast cut through by the waves of the ocean, and is composed of a vast semicircle of dunes stretching from the mouths of the Scheldt to those of the Ems and the Weser. Far from having gone beyond this original coast-belt, the greater part of the Dutch rivers have formed estuaries, and the wide sheets of the Bies-bosch, the Zuyder Zee, and the Dollart, constitute unquestionable testimony of the invasion of the sea-water. The alluvial tracts of Holland do not, therefore, present the character of a delta properly so called.

Deltas are not formed solely on the lower portion of a river's course; they also exist at all the points of the river where former lacustrine basins have been filled up by one or more several affluents. At these spots, the principal watercourse and its tributaries divide into several branches, radiating in a fan-like shape across the alluvial plain; sometimes they even cross one another so as to form a complete network. About the middle of its course, the Mississippi receives two considerable affluents from the west, the Arkansas and the White River. The principal river and its two tributaries are united by a network of innumerable *bayous*, or channels, which, at every inundation, change their course and their depth, falling alternately into one or the other of the three currents, according to the respective height of their waters. When the Mississippi is very high, it disgorges its surplus water into the system of *bayous*, and the latter empty into the Arkansas and the White River. During the low-water season, on the contrary, when the water poured by the Mississippi into the marshes above has had sufficient time to flow from lagoon to lagoon down to the White River, the latter feeds the network of *bayous* which connects it with the Mississippi and the Arkansas. When the latter river is swollen more than usual after heavy rains in the western prairies, then the pressure of its water drives back that of the Mississippi, and, for a time, the Arkansas takes possession of the common delta. On the banks of the Amazon River all these phenomena take place with much more grandeur; at the mouth of the Japura especially, the principal current forms with its affluent an inextricable network of false rivers, which seem to flow indifferently in any direction, and, for a space of several thousand square miles, direct their surplus waters from marsh to marsh through the virgin forests. This system of *furos*, as they are called in South America, resembles those congestions in the human body, when the too great abundance of blood gives rise to a system of false arteries and veins.

CHAPTER LIII.

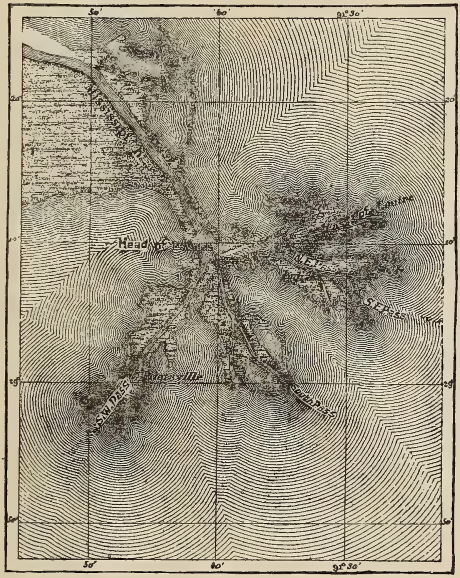
THE CHANNELS OF THE MISSISSIPPI.—"WORKING RIVERS."—SHIFTING OF THE POINT OF BIFURCATION.—RAISING OF THE RIVER-BED ABOVE THE DELTA.—ALTERATION IN THE SITUATION OF MOUTHS OF RIVERS.

IN a geographical point of view, it is important not to confound apparent deltas with the real deltas of alluvial earth. Thus, the basin of the Mississippi, in which there is opportunity for studying so many other hydrological phenomena, exhibits several instances of emissaries which must not be looked upon as branches of the delta. The Achafalaya, in fact, is not a branch of the Mississippi, as it is not fed by the latter; it is, on the contrary, a continuation of the Red River, which sends down to the Achafalaya a portion of its water directly, and another portion indirectly, by using for nearly a mile the bed of the Mississippi itself. The Plaquemine and Lafourche *bayous*, which, during floods, receive a small portion of the water of the Mississippi, are not regular fluviatile beds, like the branches of the Rhone, the Nile, and the Po; they are mere channels communicating between the inland lakes and marshes, and have become united to the Mississippi by an erosion of the banks of the river. It is, indeed, owing to the labour of man—that is, to the side embankments and the drainage of the marshes near it—that the Lafourche *bayou* has assumed the aspect of a river for so large a portion of its course, and now no longer disappears, as it once did, in a labyrinth of pools and marshes. The Manchac, or Iberville *bayou*, which used to reach the sea through the Amite River and the Lake Maurepas, is now completely obliterated by the alluvium and masses of entangled trees; but it has always been a mere flow of no great importance. Thus, the delta proper only commences at the "Head of the Passes," and this sheath-like bed, through which the Mississippi rolls between two narrow banks of alluvium, one side of which is sea-shore and the other river-bank, is, geologically speaking, the sole bed of the river. Projecting from the continent like an arm, it pushes out for 62 miles into the sea, and spreads over the water the branches of its delta, like the fingers of a gigantic hand. A Hindu might well compare the extension of the mouths of the river to an immense flower opening over the ocean its serrated corolla.

These narrow embankments of mud, brought down into the open sea by the fresh water, present a striking spectacle. In several places these banks are only a few yards thick, and during storms the waves of the sea curl over the narrow belt of shore and mingle with the river. The soil of the banks becomes perfectly spongy; it is not firm enough to allow even willows to take root, and the only vegetation is a species of tall reed (*Miegea macrosperma*), the fibrous roots of which

give a little cohesion to the ooze, and prevent its being dissolved and washed away by the succession of tides. Farther down the reeds disappear, and the banks of mud form, are washed away, and form again, wandering, so to speak, between the river and the sea, at the will of the winds and tide. On the left bank of the south-west passage, which is used for the largest ships, the plank-built huts of a small pilots' village have been fixed as delicately as possible. These constructions are so light, and the ground that carries them is so unstable, that they have been compelled to anchor them like ships, fearing that a hurricane might blow them away; still, the force of the wind often makes them drag their anchors. Below, the banks of the Mississippi are reduced to a mere belt of reddish mud, cut through at intervals by wide cross streams; still farther down, even this narrow

Fig. 152.—Mouths of the Mississippi.

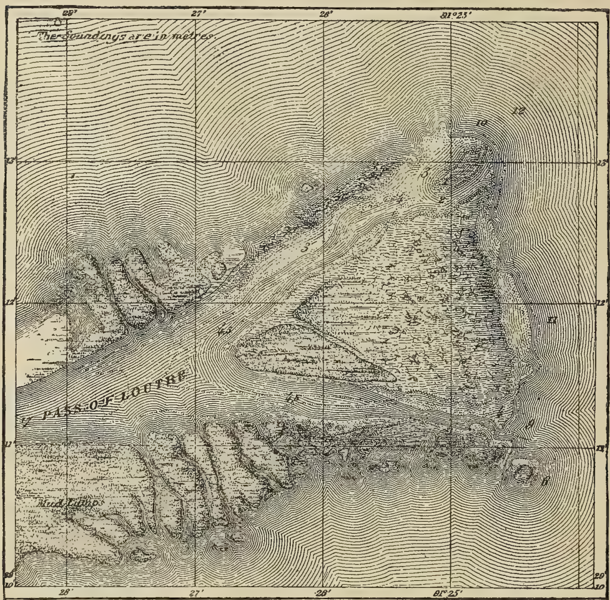


belt comes to an end, and the banks of the river are indicated by nothing but islets, which rise at increasing distances from one another, like the crests of submarine dunes. Soon the summits of these islets assume the appearance of a thin yellow film floating on the surface of the water. Then all is mud; the land is so inundated with water that it resembles the sea, and the sea is so saturated with mud that it resembles the land. Finally, all trace of the banks disappears, and the thick water spreads freely over the ocean. After getting clear of the bar, the sheet of water which was the Mississippi preserves, during floods, the yellowish colour by which it can be distinguished for about twenty miles; but it loses in depth all that it gains in extent, and, gradually depositing the earthy matters which it holds in suspension, becomes ultimately perfectly mingled with the sea.

In calm weather, the union of the fresh and salt water presents an interesting

spectacle, affording some similarity to the meeting of the tide and the river-current in an estuary. Gliding in layers of increasing thinness over the weightier masses of the ocean, the muddy water, on escaping from the mouths of the delta, swims like oil on the surface of the waves, and the sailors are able to collect it, without difficulty, by skimming the surface. Ships, as they pass, break through this light yellowish sheet, and leave behind them a long track formed by the blue and transparent water of the sea. A contrast of the same nature is produced at the spot where the Gulf Stream causes the belt of the water of the Mississippi to swerve to the east; one might fancy that a straight line traced out by a ruler separated the two diversely coloured waters as far as the horizon. Finally, the sheet of fresh water, becoming very thin, is broken up into little turbid islets,

Fig. 153.—Loutre Pass.



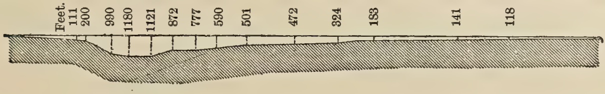
surrounded with salt water. They are often full of vegetable *débris*—they are then edged with breakers in miniature, which give them a border of foam. The sounding-line let down to the bottom of the sea off the mouth of the river finds the mud of the Mississippi as far as the coral banks of the Florida coast. The accompanying plates show the difference in the depth of the sea between the axis of the Mississippi and those portions of the gulf which are situated immediately to the south.

The fluviatile tracts of alluvium, which are constantly forming before our eyes, may be classed among the most important geological phenomena in the history of the globe. Owing to the quantity of mud which the masses of running

water bring down to their outlets, the shore-line is incessantly changing, and continents are increased in area. Carl Ritter has given the name of "working rivers" to those watercourses which deposit a large quantity of alluvium in deltas and push their shores farther and farther into the midst of the sea. Every river, indeed, takes its share in this labour; but in great deltas the earth quite visibly encroaches upon the ocean. At the mouths of several rivers the lifetime of a man would be a period long enough for the salt bay to be converted into a plain, and the floating sea-weed beds to become a magnificent forest.

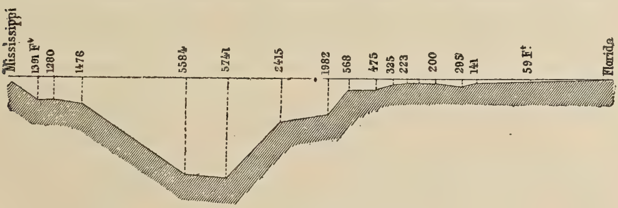
The deltas themselves, the vast plains which, as Herodotus says, are the "gifts of rivers," bear witness to the geological importance of running waters in the formation of continents. But the investigations which have been made up to the

Fig. 154.—Depths of the Gulf of Mexico in the line of the Mississippi Current.



present day enable us to estimate the progressive course of these alluvial formations in but a small number of rivers. In fact, the problem which has to be resolved is a very complex one. In the first place, it would be indispensable to prepare at intervals exact charts of the sea-coast and the depths of the sea in the vicinity; next, it would be requisite to strictly apportion the quantity of sediment brought down in each season of the year by the water of the river, and to ascertain the amount of alluvium which is lost along the coast. Lastly, in the beds of the delta itself, it would be necessary to distinguish between the *débris* washed away from the adjacent coast and that which is brought down by the river; for when a muddy point is formed, the currents along the shore always drive upon it a constantly increasing bank of sand. Some day, doubtless, more exact observations will enable

Fig. 155.—Depths of the Gulf of Mexico South of the Mississippi Current.



us to trace out the journey of the alluvium down the river that carries it along; we shall ascertain the average time that elapses before the rock rolled down by the torrent is broken up into pebbles, and then in succession reduced to gravel, sand, and impalpable mud; we shall learn the number of resting-places that the *débris* avail themselves of in bend after bend from the river's source to the sea. Perhaps, even by the mere observation of the alluvial layers, we shall be able to discover the age of the bed, as we ascertain the age of a tree by its concentric rings. We must, however, confess that this class of geographical observations is scarcely inaugurated, and that it would require an enormous staff of *savants*, which does not at present exist. We are, therefore, compelled to form rather rough estimates as to the results

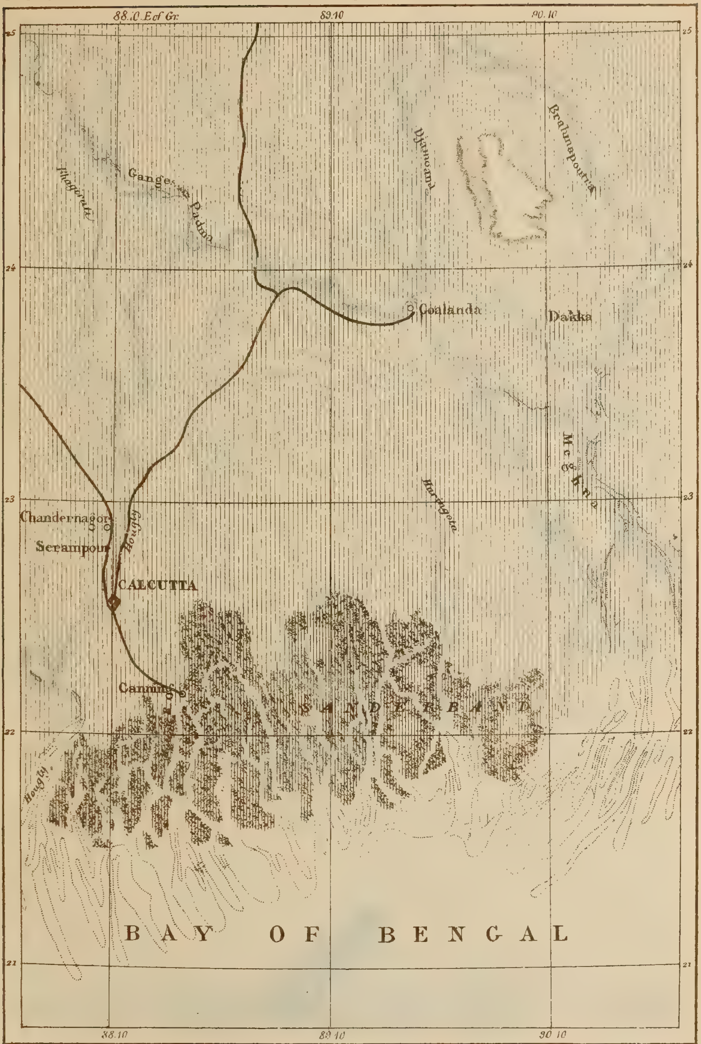
of the labour of rivers; this is the case as regards the Hoang-ho, which is probably more loaded with alluvium than any river in the Old World.

This river owes its name, Hoang (yellow), to its muddy sediment, which, far out at sea, soils the purity of the sea-water, and is carried by the currents as far as the coasts of the Corea. The delta which it has formed during the present period extends over at least 96,000 square miles, and constitutes one of the most important provinces in China. The tracts of alluvium have joined to the mainland the mountainous mass of Shantung, which once stood alone in the midst of the sea. Fresh islets have slowly risen from the bed of the sea, and the detritus is deposited in quantities so great that, according to a calculation made by Staunton at the end of the last century, they would be sufficient in the course of sixty-six days to form an isle a square mile in extent and 118 feet in depth. According to the calculations of the same author, the whole of the Yellow Sea is destined to disappear entirely in about 24,000 years; but this period should be at least doubled, for the waters of this sea are much deeper than Staunton supposed.

The English authors who have written on the subject of the lower regions of the Sunderbunds—that prodigious mass of alluvium brought down by the Ganges and the Brahmaputra, the terrible "son of Brahmah"—afford us but uncertain information as to the lengthening of the mouths of the rivers. According to Rennell, the Ganges alone sends down in its water from 5 to 6 cubic yards of mud a second; nevertheless, the line of shore extending from the mouth of the Hugly to the estuary of Huringota, which consequently limits the Gangetic portion of the delta, appears to have been subject to but very slight modifications during historic times. The promontories and the islets of the eastern portion of the delta encroach much more rapidly on the sea; for on this side the waters of the Brahmaputra, which on the average are charged with twice as much mud as those of the Ganges, pour into the Bay of Bengal. A great quantity of the alluvium which is brought down by the two rivers is lost in the immense marine depression which lies about 31 miles from the mouth of the Ganges, which is called the "Great Swatch."

The Nile—that typical river which was the subject of study to the Egyptian hierophants thousands of years ago—which spreads out the graceful delta formed of its own alluvium, is incomparably better known as regards its lower course than any river of Asia. This great watercourse, which may be compared in the length of its bed to the Mississippi and the Amazon, scarcely surpasses rivers of the third class, such as the Rhone or the Po, in the importance of its liquid mass, and is much inferior to them in the quantity of its alluvium. It has been calculated that if all the mud brought down by the mouths of the Nile was thrown up uniformly on the coast, the latter would advance about 13 feet a year. The low points of alluvium which are deposited near the Rosetta and Damietta mouths increase on the average, the one 34 acres and the other 39 acres every year, which gives only 3 feet of annual progress for the front of the delta, the convexity of which is 186 miles in length. If the advance of the alluvial deposits was not more rapid during past ages than it is at present, it must have taken the Nile no less than 74,253 years to deposit, grain by grain, the triangular plain of the delta, comprising an area of 8,610 square miles.

The fact is, that the Nile leaves the greater part of its alluvium on the plains by the river-side; added to this, the extension of the water over the two banks, and the diminution of the current which results, necessarily cause the fall of a certain quantity of sediment on the bottom of the river-bed. The French *savants* of the Egyptian expedition found that the rise in the bottom averaged 4·960 inches a



Alluvial Soil   Land annually flooded

0 to 10 m.   10 to 50 m.   50 to 100 m.   100 to 150 m.   150 to 200 m.   200 to 500 m.

$\frac{1}{2\,743\,000}$

Kilometres

10 20 30 40 80

century. This gradual elevation of the bed doubtless corresponds with a similar change in the level of the two banks of the river. By measuring the bed of alluvium in which the statue of Rameses II. is buried at Memphis, Mr. Horner came to the conclusion that during the last 3,215 years the soil of Egypt had risen 3·043 inches in each century. It is probable that in future the soil will be raised more and more rapidly every year, owing to the "warpings" which are incessantly carried on by the agricultural inhabitants on each side of the river. Now that a vast system of skilful cultivation has appropriated the banks of the Nile, and that steam-pumps are drawing off the water of the river in every season, the liquid discharge and the mass of sediment must diminish at the mouth; and if this impoverishment of the Nile continues to go on in the same proportion, we might perhaps calculate

Fig. 156.—Delta of the Nile.

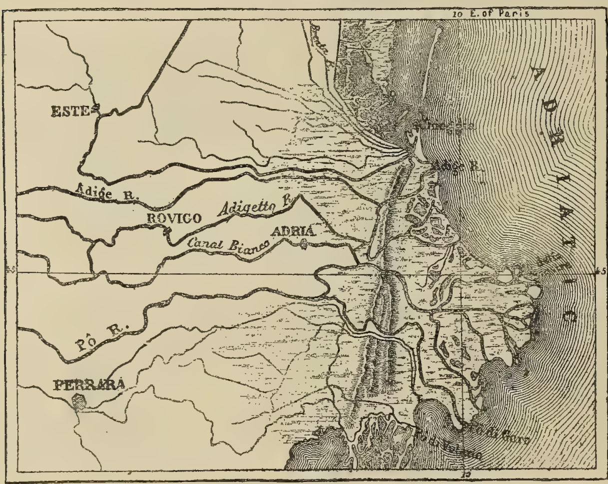
the future date when the Nile, being exhausted by the irrigation canals, will no longer send down to the Mediterranean either a drop of water or a grain of sand.

It may be readily understood that the best known river-delta must be looked for in Europe, and in that country of Europe which, for so many centuries, has devoted itself most earnestly to all questions relating to hydraulics and irrigation. The delta we speak of is that of the Po. Owing to the testimony afforded by history, the monuments left by the ancients, and the operations of the engineers of the Middle Ages, we are enabled to follow with the mind's eye the progress made by the alluvium of the river during the last twenty centuries. In some spots, especially round the lagoon of Comacchio, there are secondary deltas, the encroachments of which may be measured with mathematical exactitude, for these tracts are, so to speak, of human creation, and have been altogether deposited since the opening of artificial channels and sluices.

Notwithstanding the shortness of its course, the Po is one of the most remark-

able "working rivers" in the whole world. The gradual subsidence of the shores of the Adriatic, which is estimated by Donati at 6 feet at least since the foundation of Venice, does not prevent the river encroaching without intermission on the domain of the sea. Ravenna, which once, like another Venice, stood in the midst of lagoons, its outer rampart being bathed by the Adriatic, is now situated far from the gulf in a plain filled with the alluvium of the Po. We also know that the town of Adria, the ancient emporium of the Adriatic, to which, indeed, it gave its name, is now 21 miles from the extreme point of the shore. This is a proof that in two thousand years the annual average progress of the delta has been 55 feet; but at the present day the advance of the alluvial tracts is much more rapid. The patient investigations of Lombardini have established the fact, that the river brings down every year 15,015,600 cubic yards of mud and ooze, that is about 1·781 cubic yard a second, and enlarges the shore of its delta 76

Fig. 157.—Mouths of the Po.



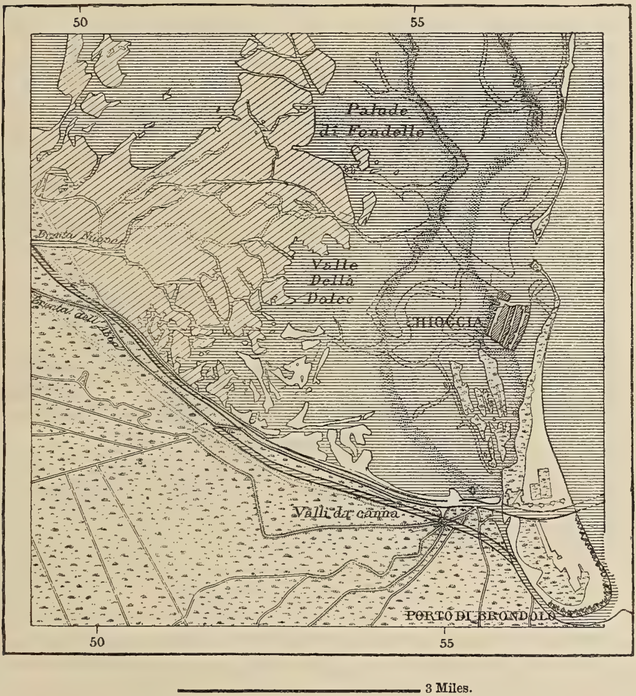
yards. A chain of dunes, now left inland by the encroachments of the alluvial deposit, still points out the direction of the former sea-coast. The enormous amount of increase in the deposit at its mouth, which is thus accomplished by a river of the third class, is readily explained by the embankments, which compel the Po to carry down to the sea the whole of its alluvium, whilst the Nile and the Ganges, during each period of flood, spread over a great area of land, the level of which they raise by their deposits.

No less charged with matter is the neighbouring river Brenta, which is also causing the land to advance rapidly seawards, to the great injury of the city of Chioggia. It had formerly been diverted from its natural course by the Venetians, who caused it to flow along the south side of the Chioggia lagoon to the port of Brandolo. But the fall of this torrential stream having been thereby reduced, the danger of bursting the side embankments was increased, and after a great inunda-

tion, it was resolved to shorten its course by turning it into the lagoon. The engineers Fossombroni and Paleocapa, who carried out the works, supposed that the Brenta and the parallel Norissimo Canal would lose themselves in the lagoon without causing it to silt up, at least for many centuries. But in 1870, that is, twelve years after the cutting of the dikes, the delta of the Brenta had already created 8,700 acres of dry land; assuming that the process continued at the same yearly rate of about 52,000,000 cubic feet, the whole lagoon south of Malamocco would be filled up by the year 1908. But even before this date Chioggia itself

Fig. 158.—Alluvia of the Brenta in the Chioggia Lagoon.

Scale 1 : 125,000.



must be ruined, unless precautionary measures are taken. Since the mingling of the fresh and marine waters, maladies of all sorts have increased fivefold; the sea-faring natives, formerly noted for their robust constitutions, have become enfeebled, and Venice itself is now threatened. Hence it is proposed to close the new opening and restore the Brenta to its old channel flowing to Brandolo.

The Rhone is the most active amongst the French rivers in the formation of a delta. The promontory deposited by its current in the open sea projects much more decidedly beyond the regular line of coast than the delta of the Nile, and advances every year with a rapidity which may almost be compared to that of the

Po. In the fourth century the town of Arles was only 16 miles from the sea, whilst at the present day it is 29 miles removed from it. The advance of the alluvium has, therefore, been 13 miles during the space of fourteen centuries, or about 52 feet a year. The annual average prolongation of the shores of the principal branch of the river is, therefore, about 164 feet. But this does not prove that the *débris* brought down by the river are increased threefold, in consequence of the embankment of the land by the river-side; for the Rhone has frequently shifted the position of its outlets, by opening them alternately on both sides of the banks of mud caused by its own deposits. In this way, the increase of the delta takes place at several points in succession; on one side the alluvium encroaches rapidly, and in other places it remains almost stationary.

In the Rhone, as in the Po, an endeavour has been made to estimate, by means of the annual discharge, the quantity of matter deposited by the river. This mass

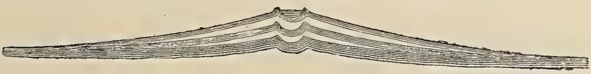
Fig. 159.—Delta of the Rhone in the Fourth Century, and at the Present Time.

is about 22,000,000 cubic yards every year. It certainly is a fact that, by direct measurements of the increase of the delta, and by soundings made on the bar, M. Reybert found that the total quantity of matter brought down from 1841 to 1858 amounted to 419,000,000 of cubic yards, which would be equivalent to an annual increase of 25,000,000 a year; but this difference may be explained by taking into account the enormous quantity of *infusoria* and small shell-fish which exist in all the newly-formed soft banks. Some specimens of the mud taken from the mouth of the Rhone contain, as M. Delesse has ascertained, as much as 30 per per cent. of carbonate of lime, proceeding, no doubt, from the remains of the shell-fish. It also appears that the proportion of the alluvium of the Rhone which is brought down to the sea, and afterwards carried away by the currents to distant shores, is very slight. Almost all the mud is absorbed in the construction of the delta, and forms the *teys* or muddy islets which make their appearance on each side

of the mouth. The soil which is thus brought down by the river is generally very fertile. The mud of the Rhone is no less productive than that of the Nile, and sanitary and irrigatory operations would soon render La Camargue another Egypt. In this respect, France has much to learn from the ancient land of the Pharaohs.

The delta of the Mississippi advances even more rapidly than that of the Po. Among all the questions in respect to the great river of the New World, the yearly prolongation of its alluvium has most of all excited the curiosity of science. How many yards does the Mississippi advance into the sea during the course of each year? How many square miles does it add to the mainland in a century? How many thousands of years must it have been at work in forming its delta, and depositing its enormous burden of alluvium? Many geologists have, each in their turn, endeavoured to answer these questions, by basing on data, which are sometimes only hypothetical, the very different results at which they have arrived. Thus, M. Elie de Beaumont, who, at that time, had not the necessary elements at his disposal, estimated the progress of the delta at 382 yards a year. M. Thomassy, comparing the ancient French charts with the American surveys, has felt warranted in fixing the annual conquest effected by the Mississippi at about 110 yards. Messrs. Humphreys and Abbot, looking upon the old chart as being too incorrect to serve as the base of a serious calculation, are satisfied with comparing the charts of Talcott and of the Coast Survey, and judge the annual prolongation of the delta to be 86 yards. M. Ellet, one of the most conscientious investigators of the action of the river, reduces the probable enlargement of the delta to 22 feet,

Fig. 160.—Gradual Rise of the Bed of the Delta.



so as to make allowance for the erosion exercised by the sea. Lastly, M. Kohl, whose hypotheses it is very difficult to understand, even if you have the maps before you, maintains that the delta of the Mississippi remains nearly stationary. It must be confessed that the differences on the point would be serious enough to render doubt "the best pillow for the wise man," if it were not that the calculations of M. Thomassy and the learned explorers, Humphreys and Abbot, undoubtedly surpass all the others in scientific value. The average advance of the delta during the two last centuries must, therefore, be estimated at from 86 to 110 yards.

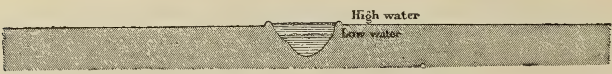
This rapid progress in the alluvium is, perhaps, very much owing to the cutting down of the forests, which has rendered the soil of the banks much more movable. To this cause for the growth of the delta must be added the construction of high embankments on the banks of the Mississippi and its tributaties; for, as only a small portion of the mud is able to settle at the sides, a much more considerable mass is carried down to the mouth; nevertheless, the delta is not increased in proportion. The more the area of alluvium gains on the water, the deeper is the spot in the gulf in which the matter (estimated at seven cubic yards a second) is deposited. At the lower extremity of the delta of the Mississippi, the thickness of the bed of sediment is not less than 98 feet; and soundings have shown that the river will soon reach the edge of the deep abyss through which the Gulf Stream flows. At 11 miles from the south-west channel, the bottom of the sea is 885 feet from the surface, and this depth rapidly increases to more than 5,000 feet. Being, of course, unable to fill up these gulfs, where the rapid currents would carry

the alluvium into the open sea, the Mississippi must be content with obstructing the lateral bays, or with extending towards the east, in the direction of Florida. Some day, the delta of this river will be bounded on the southern side by a rapid slope, like that which is formed by the Rhone in the Lake of Geneva, and by the Congo in the Gulf of Guinea. At the mouth of this latter watercourse, the sounding-lead falls rapidly from 30 to 1,600 or 2,000 feet.

When the river-outlets are left to themselves, the spot in the river where the bifurcation takes place gradually shifts its position in a down-stream direction in proportion as the mouths advance towards the sea. In fact, the current, striking against the upper point of the delta, must necessarily wash away the two banks of the island which it has itself formed by the deposit of its alluvium. A remarkable instance of this alteration in the place of bifurcation of the river-outlet may be noticed in the Egyptian delta. At the time of Herodotus, Memphis was the spot where the Nile divided into two branches; it now forms its fork at Cairo, more than 18 miles from the spot where it took place 2,400 years ago. The upper point of the delta will henceforth remain stationary, owing to the barriers constructed just above the apex of the two principal branches of the river.

The prolongation of the delta has a proportionate and constant tendency to raise the bed of the river above the mouth. The calm and immense river which empties itself into the sea, obeys the very same laws as the boisterous torrent pouring into a lake. In proportion as it pushes its branches further into the sea, it must form a slope considerable enough to insure the discharge of the mass of water. This

Fig. 161 —Section of the Mississippi at Plaquemine.



slope can only be produced by the gradual raising of the river-bed. It is evident that this rise will be the more rapid, the better the shores are protected by embankments against inundations; for the alluvium must, in this case, all descend to the sea and lengthen the extreme points of the delta.

The results produced on the action of rivers by lateral embankments have, however, been singularly exaggerated. Pessimists have often pointed to the example of the Po as a proof of the rapid heightening of the river-level which is brought about by the construction of embankments; "but this oft-repeated assertion is not based on any real fact. Cuvier was entirely mistaken in stating, according to a communication from M. de Prony, that the surface of the water of the Po is now higher than the roofs of the houses in Ferrara." This, unfortunately, is one of those accredited errors which it is difficult to dispel, on account of the great names which countenance them. Elia Lombardini has proved, by strict measurements, that the mean level of the Po exceeds in but very few spots the level of the ground in the adjacent country. In 1830, at the time of one of the highest floods of the century, the surface of the Po was scarcely ten feet above the level of the pavement in front of the palace at Ferrara. The mean height of the water over the whole course of the river is considerably below that of the neighbouring plains. To make up for this, the streams of the Reno, the Adige, and the Brenta, which empty into the delta of the Po, have certain portions of their beds higher than the adjacent country. The fact is, that having so lately left the mountain gorges, they still retain their characteristics as torrents, and, like all

mountain streams, raise a bank of *débris* below the ravines of erosion. The exceptional height of the Adige, the Reno, and the Brenta must not, therefore, be attributed to the dikes which border the lower portion of the course of these streams, but to the impetuosity of the water above. The calculations of Humphreys and Abbot prove that the mouths of the Mississippi must project 24 miles farther into the sea for the river to rise only one foot under the ramparts of Fort St. Philip, 31 miles above the south-west channel.

If, however, rivers which are subject to high floods, such as the Nile, the Po, and the Mississippi, are, during inundations, higher in level than the plains by the river-side, this fact is owing to the lining of alluvium which is gradually formed on the banks. During the period of flood, the waters which pour over the banks are retarded by a thousand various obstacles—trunks of trees, bunches of plants, mounds, palisades, buildings—and consequently they deposit on the ground much of the sediment which they contain; before they leave the banks and flow far and wide into the plains they are comparatively purified. The effect of this is a gradual elevation of the banks and the ground near them to a level somewhat above that of the country generally. Above New Orleans, the natural inclination of the soil is very marked; from the shores of the Mississippi to the marshes in the interior, the difference in level is not less than 13 to 16 feet, and at some points even this considerable slope is exceeded. The banks of the islands scattered about in the lower courses of rivers are likewise raised by inundations to a point above the level of the surrounding country. The Lower Parana, the Volga, and a number of other large watercourses present, near their mouths, multitudes of islands, the raised banks of which circle round pools or marshes.

The elevation of the lower course of a river above the surface of the surrounding plains, explains in the most simple way the continual shifting of the outlets of the delta. As soon as a breach is made in the lining of the bank, a considerable portion of the running water immediately escapes through this opening, and descends to the sea over a new bed which it hollows out for itself across the low-lying tracts, marshes, and lagoons; these are natural crevices, similar to those which occur in embankments raised by man's labour. Thus, when the economy of a river has not been modified by human agency, its outlets are of a changing character and move across the delta, depositing their sediment in the lagoons, so as gradually to elevate the soil, and to bring it everywhere to the level of the high floods. Every delta becomes modified, even during the historical period, in the number, direction, and importance of its branches. Of the seven famous mouths of the Nile, five have now ceased to exist except during floods; the two which still remain open—those of Rosetta and Damietta—appear, according to Herodotus' statement, to have been dug out by the labour of man. During the last 3,000 years, the branches of the Lower Hoang-ho have undergone similar modifications in their course, which are more remarkable on account of the immense extent of ground over which they have constantly wandered. Still more strangely, the Oxus in Turkestan, which now falls into the Sea of Aral, is said in former days to have been a tributary of another sea, and flowing to the Caspian; the traces of its supposed abandoned bed are shown here and there in the desert.

In consequence of the incessant modifications to which the lower portions of rivers are subject, it often occurs that two watercourses which were once perfectly distinct and independent of one another, become united in their deltas and principal outlets. We may mention the instance of the Shat-el-Arab. In like manner, the Adige and the Po, which communicate with one another by lateral branches,

have a tendency to join one another completely in a common bed, and nothing but extensive operations has prevented, up to the present time, the perfect junction of these two rivers. The Mississippi, so remarkable in all other respects, presents, according to Ellet, the phenomenon of three former rivers united in one. At one time the river Wachita ran down to the sea through the Achafalaya, which is now an overflow-channel of the Mississippi, but was then a distinct river. The Red River, too, flowed in the valley of the Têche, where it has left numerous traces of its passage. The opposite windings of the Red River and the Mississippi gradually approached one another and then united; the Wachita-Achafalaya has been, as it were, cut into two parts, one of which, the northern portion, is become an affluent, and the other, the southern portion, an effluent of the Mississippi. Similar phenomena are observed in the delta common to the Ganges and the Brahmaputra. There seems to be a real conflict between the branches of these two rivers; they first come together and are then mutually repelled; they sever one another and fill each other up.

Thus, whilst in some cases distinct rivers unite, others, on the contrary, which were once combined, are now separate, and take contrary directions. As a striking instance of this double series of hydrological phenomena, we may mention the two rivers of Cilicia, once called the Sarus and the Pyramus, now known as the Seihoun and the Jihoun. These streams, which project their alluvial deposits more than six miles beyond the outline of the former coast, fall into the sea sometimes through two distinct mouths, sometimes through one outlet common to the two rivers. Since the days of Xenophon, the two streams, which then flowed in beds some distance from one another, have united three times, and three times have again separated. In the space of twenty-three centuries, says M. Langlois, six complete revolutions have taken place in succession in the course of action of the Sarus and the Pyramus.

CHAPTER LIV.

BARS OF RIVERS.—OPERATIONS UNDERTAKEN FOR DEEPENING THE MOUTHS OF RIVERS.

NOTHING is more variable than the channels at the mouth of a river. Thus—only to mention the Mississippi—this river has now five channels, the south-west, the south, the south-east, the north, and the Loutre, which is a ramification of the one preceding. Sometimes one and sometimes another of these outlets becomes the real mouth of the river, and the stream takes to them and abandons them in turn. The fact is, that the Mississippi, having considerably elongated its principal outlet by the alluvium it has brought down, is compelled to seek some bed which is shorter and consequently more inclined, in order to pour down its mass of water; when this fresh outlet is likewise pushed out too far into the sea to afford the requisite slope, the river turns either to the right or left to clear for itself a third place of issue. At the time of the first attempts at colonisation in Louisiana, the south-east channel was the principal one; but this gradually became obstructed, and the north-east mouth was next the most important. The mass of water in this channel diminished every year, and in 1853 there was not more than 8 feet of water on the bar, and small coasters were the only vessels which ventured over it. Since 1843 the south-west channel has become the real mouth of the river, through which almost all large ships try to enter. In 1853 there were $16\frac{1}{2}$ feet of water; but constant labour was necessary to maintain even this depth, for the quantity of water constantly tends to diminish, whilst in the Loutre channel it is gradually increasing. At present the only navigable channel is that of the south, which has a mean depth of from 16 to 24 feet.

However much they may shift their course, still most rivers are obstructed by a bank of sand or mud, to which mariners have given the name of "bar." These banks of alluvium are for the most part deposited in the form of a crescent off the mouth of the river, and, turning their convex sides towards the open sea, mark the precise spot of the line of breakers which rise in rough weather. They may be deposited in different modes, according to the quantity and impetus of the river-water, the mass of sediment which the latter holds in suspension, the configuration of the coast, and the general direction of the winds and currents out at sea. There are, however, a few hydrological problems which have given rise to animated discussions among geographers and engineers, for which, too, many various or contradictory solutions have been propounded. The fact is, that the question is altogether a complex one, and presents itself under a new aspect at the mouth of each particular river. It certainly is the case that, as regards all rivers, the

collision of the two liquid masses flowing in contrary directions is the primary cause of the formation of bars; but the materials which are employed and the progress of the work vary singularly.

At first sight, the origin of a bar seems a matter easily to be understood, especially in the case of rivers with waters much charged with mud. It is thought that the current of fresh water, being suddenly arrested in its career by the sea water, immediately precipitates the matter which it held in suspension, and thus gradually forms the kind of sill which rises between the bed of the river and the ocean. This, however, is not the exact mode of formation. The flow of fresh water, being but little retarded, continues its movement above the salt water coming in a contrary direction. The sediment which is let fall by the current of the river is intercepted by the counter-current and borne up stream. At the same time the heavier alluvium, which makes its way to the sea by gliding over the bottom of the river-bed, is arrested in its progress and is mingled with the sand and the innumerable organic remains driven in by the waves. Thus an increasing cushion of mud is formed in front of the rising tide flowing to meet the river, and in this way the heaps of *débris* which constitute the bar are gradually accumulated. This obstacle, being produced by the shock of two opposing currents, shifts coincidently with the scene of the conflict. During floods, the impetus of the mass

Fig. 162.—Longitudinal Section of the Bar of the Mississippi.

of fresh water becomes sufficiently strong to remove the whole bar and to carry it farther in advance; but, on the other hand, when the water of the river is low, the tide resumes the preponderance, and the bar is again driven back. The barrier shifts its place, sometimes in one direction, sometimes in another, and is incessantly seeking to preserve its equilibrium between the two opposed forces which impel it.

The bars of the delta of the Mississippi may be quoted as an instance of this mode of formation. Over the bar which obstructs the entry of the principal channel, and the most practicable of all those on the coast of the Gulf, there is an average depth of 16½ feet. The alluvium of the bed, being kept in constant motion by the waves and the current of the river, is in an almost liquid state. Vessels have been known to cross the bar without any other assistance than their sails, although their hulls were, for more than half a mile, buried in the mud to a depth of 6 feet. Notwithstanding the soft nature of the ooze, vessels may still incur considerable danger in crossing the bar. Those that do not avail themselves of a steam-tug are sometimes taken athwart by the wind and driven irretrievably upon the banks. It is often impossible to get them off again; the motion of the keel stirs up and sends into the current the smaller particles of the mud, but the heavy sand remains, and ultimately becomes cemented round the bottom of the ship.

There are some bars which are almost entirely the work of the sea; these are banks of sand or shingle which the waves throw up across the outlet of a river, thus continuing the line of shore. Barriers of this kind form in front of water-courses running into a sea agitated by violent storms, or raised every day by a very strong tide. The flow coming from outside ascends far into the river-mouth, and forces the current meeting it to deposit its heavier alluvium at some considerable distance above the bar properly so called. The earthy particles held in suspension by the current of the river cannot be precipitated on account of the continual agitation which is kept up at the entry by the breakers and the swell; they remain mixed with the masses of water, and are driven up-stream by the flow, or carried out to sea by the ebbing tide. Even the fine sand which the waves throw up on the bar is not allowed to remain there for long; it is again stirred up by the water which brought it, and it finds a resting-place only in those spots where the motion of the waves ceases. The heavy sand, the shingle, and the stones which the waves drive before them without carrying them along in eddies are the only materials which constitute the bar. Like the banks of mud in river-deltas, this line of *débris* is incessantly shifting its place, sometimes up-stream and sometimes down-stream, seeking the exact line where an equilibrium exists between the ebb and the flow. When the river is flooded, the force of the water running down carries the bar farther out to sea; on the contrary, when the river is low, the tide gains the ascendancy, and pushes the sand up into the mouth of the stream.

In France, these phenomena have been best studied at the formidable bar of the Adour. Thanks to the submarine charts which the engineers prepare twice every month, we may trace out, so to speak, by the eye, all the fluctuations of the bank of *débris*, and all the causes of its movements can readily be taken into account. In this bar, however, there is every evidence to show that the materials forming it are brought up by the waves. The soundings that have been made in the bed of the Adour, as far up as 15½ miles above Bayonne, uniformly show a bottom of mud or fine sand; but it is ascertained that the bank at the mouth is composed of heavier sand and shingle, proceeding, no doubt, from the cliffs of the Spanish coast.

The bars of rivers, which have always been an obstacle and a source of danger, are at the present time more troublesome to deep navigation than they have ever before been. It certainly is the case that, thanks to the steam-tugs, vessels with a light draught of water are able to follow the direct channel, and can cross the difficult part in the space of a few minutes; but, nowadays, commerce is no longer contented to employ the small vessels of former times; it requires ships of heavy burden, carrying large quantities of merchandise, and drawing a considerable depth of water. Many a river-port, once the resort of whole navies, is now abandoned on account of the bar which cuts it off from the ocean, and is frequented only by coasting vessels; commercial vitality has gradually left it. Thus the deepening of their river-mouths is become a most important question in some sea-coast towns. If they could only succeed in doing away with the bar, these towns would increase suddenly in wealth, population, and importance. If the bank of sand must remain fixed across the outlet of the river, the city is on its way to certain ruin. Every engineer recommends his own special plan as being adapted to avert the danger; each promises that he will correct those river-outlets which Vauban characterised as "incorrigible." But only too frequently operations are undertaken without taking account of the numerous causes which determine the formation and fluctua-

tions of the bar. Amongst all the immense works which have been carried out at the mouths of rivers, many have become useless, or even absolutely injurious to navigation. Millions and millions of money have been thus cast into the ocean and purely wasted.

The most simple means, and that, indeed, which is always resorted to in the first place, is *dredging;* but this plan is evidently merely provisional, and in the present state of science can scarcely be considered as a remedy of a lasting character. Moving an obstacle is not doing away with it; besides, the flotilla of dredgers which can be employed on a bar in removing the alluvium is always insufficient in number. Even if they were constantly at work, there would be little or no result, for the inexhaustible ocean would take up the task of providing the alluvium and raising the bar; the obstacle would be merely shifted in place.

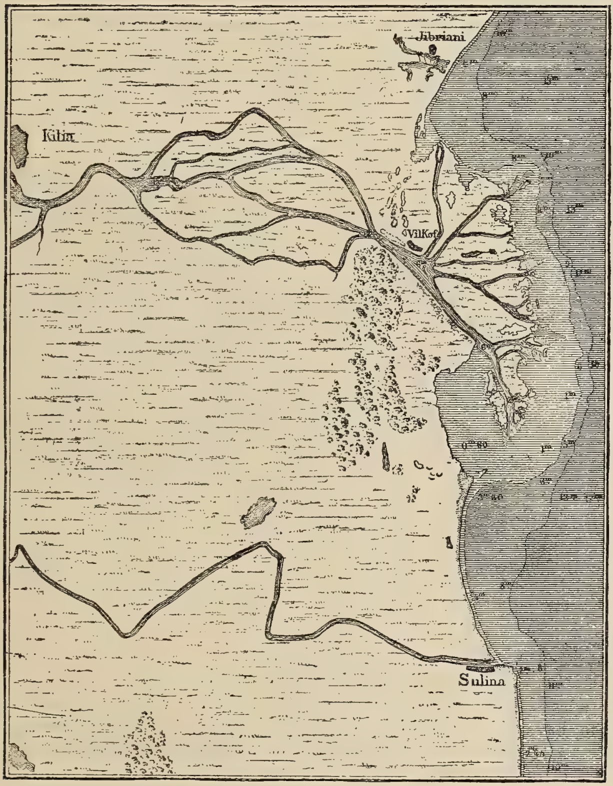
Instead of moving the mud, the more simple plan has often been tried of sending it into the current by keeping the water in a constant state of agitation. For a length of time it has been a recognised fact that, after the passage of several ships there is an increased depth of water on bars composed of mud and fine sand: the particles stirred up by the keels are carried away by the current. This phenomenon may readily be produced by artificial means. More than a century back a French company applied this remedy in the principal channel of the Mississippi, by causing heavy iron harrows to be dragged over the shifting bed of the river. Recently, in 1852, the same plan was applied, and the Federal Government employed on the bar a certain number of steamboats, which kept the mud on the bottom incessantly in motion by means of drags or harrows, and thus prevented its precipitation. According to a popular tradition, mentioned by M. Engelhardt, a Turkish Pasha formed the same idea as the American engineers. He obliged every vessel which left the Danube to drag astern, while crossing the bar, a harrow attached to a heavy chain. In both cases the agitation of the water seems to have produced a favourable result. The Pasha succeeded in maintaining a channel of about 13 feet deep through the Sulina bar, where formerly it was not above half this depth. By the same plan the American engineers obtained nearly 20 feet of water in the south-west channel. In a similar way, in order to force the torrents to deepen their beds, the inhabitants of the Piedmontese Alps used to plough up the tracts of pebbles which were brought down by the floods.

Unfortunately, this simple method of improving the condition of the bar produces no lasting result, and the work always has to be begun over again; for the bank forms again whenever the drags allow a moment's respite to the sediment held in suspension by the water. Besides, when the water is low in the river, the operations must be suspended, or the sea would drive back all the sediment in an up-stream direction, and thus contribute to the silting up of the river-bed. It must also be remarked that measures of this kind are only practicable in rivers where the bar is composed of small particles, and is not subject to all the fury of the wind and the billows. At the mouth of the Adour, for instance, what immense harrows it would be necessary to use to move the beds of shingle driven up by the storms!

A system of moles and jetties is, therefore, the plan that has generally been resorted to by engineers for the improvement of the mouths of rivers. This plan is somewhat similar to that of the embankments which have been employed, with various degrees of success, on the middle courses of rivers; but the marine dikes have not always produced favourable results, and a great many experiments which seemed to offer good chances of success have entirely failed. Among the under-

takings of this kind which have been the most costly and the most useless, we may mention those which have been carried out in the delta of the Rhone. It was hoped that, by confining the mass of water in a narrower channel, and compelling it to run into the sea through a single outlet, a current would be produced which would be strong enough to clear out the passage to a considerable depth, and thus to allow ships of a deep draught of water to enter the river. In 1852, Surell, the engineer, closed up the various *graus*, or "passages" (from the Latin *gradus*, a

Fig. 163.—Mouths of the Danube. Kilia and Sulina Branches.

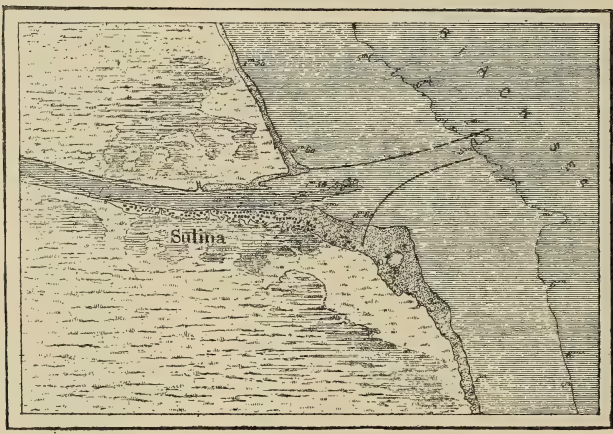


step), through which the water of the Rhone found lateral outlets, and lengthened the two banks of the principal mouth by means of dikes converging one upon another, thus doubling the force of the current. The water of the river did, in fact, accomplish the work of erosion, and cleared out the channel; but fresh alluvium being incessantly brought down by the flow of the Rhone, and thrown up by the waves of the sea, a new bar formed across the mouth outside. Before the operations of embanking were begun, the average depth of the channel was 5

feet 10 inches ; at the present time it is the same, after having varied from 13 feet to $6\frac{1}{2}$ feet, and 3 feet 8 inches, according to the quantity of water sent down by the current.

A similar undertaking, attempted, in 1857, in the south-west channel of the Mississippi, had not a more favourable result, a curvilinear jetty 1,849 yards in length having been carried away by a tempest. However, the commissioner appointed by the Federal Government to study the course of action of the delta of the Mississippi, recommended the reconstruction of convergent jetties, as being a plan which was likely to keep the channel clear. Looking forward to the constant increase of the alluvium of the river in the now contracted channel, they advised besides, as an indispensable matter, that the jetties should be lengthened about 245 yards every year, leaving it open to abandon a channel and choose a fresh one when the dikes of the first outlet should have attained any immoderate length. To the piers confining the stream to a narrower bed is due the fact that the south

Fig. 164.—Jetties of Sulina.



passage, hitherto inaccessible even to light craft, has become deep enough to create the harbour of Port Eads, now frequented by large vessels.

The operations undertaken at Sulina—one of the mouths of the Danube—appear to have met with great success, but through an entirely special cause. Mr. Charles Hartley, the skilful constructor of the Sulina jetties, has taken care to push them out more than a hundred yards into the sea, as far as a point where a current generally passes along the shore tending from north to south. This current catches hold of all the alluvium which glides down over the bottom of the bed of the river, and thus hinders the formation of a fresh bar. The average depth of the channel—which was only 9 feet before the commencement of the works—is now not less than $16\frac{1}{2}$ feet, since the dikes have been constructed. It is certainly a fact, that the gradual encroachments of the whole delta of the Danube will have the effect of pushing the current itself farther out to sea, and sooner or later a second mound of sand will obstruct the mouth of the Sulina. According to

an approximate calculation, based, however, on various hypotheses, the works finished in 1860 will not become completely useless until the year 1916.

There are other mouths of rivers, especially those of the Oder in Prussia, and the Meuse in Holland, which have been permanently improved by engineering operations; we are not, therefore, entirely warranted in repeating the words of Vauban, and characterising all the bars of navigable rivers as "incorrigible." The results obtained on the Clyde, in Scotland, may especially be classed among the most important triumphs of engineering art. The water of that river was once so very shallow that ships of a deep draught of water were compelled to stop $15\frac{1}{2}$ miles below Glasgow, and the merchandise had to be reshipped in barges: at the present time great three-masters easily come up close to the quays. Besides, in a great many cases it might, perhaps, be possible to divert the mouth of a river in places where it was not possible to force a passage, and thus, by indirect means, to obtain the depth of water necessary for large ships. A deep canal, protected against alluvium by a system of sluices, would then replace the natural channel. This plan, according to M. Desjardins, is that which was adopted by the ancients in the case of the Tiber and the western branch of the Nile, which was diverted towards Alexandria. This plan, too, has been proposed by several American engineers for insuring to New Orleans a magnificent port worthy of the river which bathes its quays. Moreover, a work of this kind is being carried out at the mouth of the Rhone, by the digging out of the canal of St. Louis. This navigable channel is $2\frac{1}{2}$ miles long and 66 yards wide, and is intended to connect the river with the Gulf of Fos—so called from a former navigable canal, dug out by Marius (*fossæ marianæ*). Vessels drawing 24 feet of water will thus be able to ascend as far as the port of Arles, which at the present day has been almost abandoned by commerce on account of the deficiency of water in the channels of the Rhone. If the excavation of the canal of St. Louis meets with success—which scarcely seems a doubtful point—this great undertaking will serve as a model for the subjection of other mouths of rivers which, up to the present time, have continued rebellious to the operations of engineers.

CHAPTER LV.

ALTERATION IN THE POSITION OF WATERCOURSES IN CONSEQUENCE OF THE ROTATION OF THE EARTH.—MASSES OF WATER BROUGHT DOWN TO THE SEA BY RIVERS.—GENERAL CONSIDERATIONS.

THE sudden changes in river-beds produced by the rupture of their dikes, as well as the movements and even obliterations of their mouths, constitute, generally speaking, catastrophes of a serious character; and it may readily be conceived that the imagination of man has looked upon these incidents as among the most important facts in the history of rivers. Yet this is not the case. However great may be the influence of these sudden modifications in the action of watercourses, they are but phenomena of a secondary class in comparison with those more durable changes which the rotation of the earth brings into the economy of every river and the general physiognomy of its basin. The fact is, that the water of rivers, like that of the ocean and the aerial waves, is subject to the influence of all the great astronomical laws. Rivers, as well as the winds, have a natural tendency to shift their course, so as to effect an arc of revolution round the planet.

In fact, the running water which the earth carries round in its diurnal movement is affected differently from the solid bodies which lie upon the ground. Whilst the latter, like the mere inequalities in the terrestrial surface, describe their daily orbit round the central axis, the fluid particles which glide over the rotundity of the globe traverse in succession various latitudes, and their movement consequently varies. The speed of rotation being completely nullified at the mathematical points which act as poles, and increasing gradually as far as the equatorial regions, where it exceeds 1,470 feet a second, everything movable which tends from one of the poles to the equator must necessarily remain in the rear of the increasingly rapid terrestrial movement which carries it round, and must consequently deviate towards the west—that is, to the right hand in the northern hemisphere, and to the left in the southern. In like manner, any movable body which takes its course from the equator to one of the poles exceeds —owing to its acquired speed—the angular movement of the globe, and inevitably deviates to the east; that is, to the right in the northern hemisphere, and to the left in the southern. These facts have been rendered perceptible by the celebrated experiments of M. Foucault on the pendulum of the Pantheon; and they can easily be verified by everyone, by causing the rotation of two suspended globes, and by allowing some coloured liquid to glide over their surfaces. The trade winds and all atmospheric currents obey this law of deviation, as well as the Gulf Stream and the other flows of the ocean. Even balls rushing from the mouth of a

cannon are subject to this law; and sometimes the locomotives on our railroads, when they run off the lines. This law applies equally to all watercourses, and—provided that the configuration of the ground allows it, and that the oscillations of the terrestrial surface do not interfere—it causes running water to deviate regularly to the right in the northern hemisphere, and to the left in the southern. With regard to those rivers which flow in a line parallel to the equator, there is no force which compels them to eat away either one or the other of their banks; but they are retarded in their course if they flow to the east, and are, on the contrary, accelerated if they run towards the west.

This is the law which, for some time past, several geographers have pointed out; which, however, Von Baer has had the honour of completely bringing to light. The only difficulty is to make a choice among the numerous rivers, which may be mentioned as examples of watercourses modifying their course in the direction pre-supposed by this theory. South of the equator there are the affluents of the gigantic Rio de la Plata, which, after having watered on the west the extent of the *pampas*, are incessantly wearing away their left banks. In the northern hemisphere there is the Euphrates, which endeavours to pour itself bodily into the bed of the Hindiah, to the right of its own course; there is also the Ganges, which abandons the town of Gour, in the midst of the jungles, and shifts in its delta four or five miles to the west. There is the Indus, wearing away the stony hills of its western bank, so as to move its delta for more than 600 miles in that direction. There is the Nile, leaving its ancient bed in the Libyan desert, in order to carry its waters by the side of the Arabian chain of mountains. In like manner, in Europe, the Gironde, the Loire, and the Elbe wear away the escarpments of their right bank; and the Vistula deepens its eastern mouth at the expense of that to the left. The Rhine, in the plains of Alsace, is gradually increasing its distance from the base of the Vosges, and is approaching the mountains of the Black Forest; and so long as its course was not fixed by the continuous rampart of its embankments, it constantly gained on the territory of Baden, and bent round to the west of the hills, along the foot of which it had previously flowed. A still more remarkable fact is exemplified by the Danube, which passess in succession through a series of defiles, and always develops its windings towards the right below each gate of rocks through which it has to pass. The river shifts its place under the influence of the movement of terrestrial rotation, in the same way that a cord fastened at certain points would bend under the influence of a current. Thus, when entering the plains of Hungary, which were once a vast lake, the Danube, instead of crossing diagonally the level tract bathed by its waters, bends suddenly to the south, and then to the east, so as to take the course of the great central depression round the high ground on its right.

In European and Asiatic Russia, the normal displacement of rivers affords an especial opportunity for most interesting studies. In these countries, in fact, all those conditions are united which are most favourable to the gradual encroachment of the rivers on their right banks: they have a very considerable length of course, and the liquid masses are powerful enough to readily clear away any obstacles; there are enormous floods which periodically increase the force of erosion in the currents, and the cliffs are composed of friable rocks. Lastly, the sharp curvature of the globe is the cause of a rapid change in the speed of rotations in the various latitudes. Two centuries ago, the principal mouth of the Volga flowed directly to the east of Astrakhan: since that time the great current has successively hollowed out for itself fresh beds, tending more and more to the right, and at the present

day the branch navigated by vessels turns to the south-south-west. Above the delta the river has everywhere shifted its bed towards the west, and opposite Tchernoï-Iar, the Ashtuba, the former bed of the Volga, now lies 12½ miles from the principal current. The twenty-three towns which have been built on the western bank, also called the upper bank on account of its high cliffs, have been almost all demolished in detail, house by house, and street by street; and being thus undermined on one side they have been compelled to advance on the other

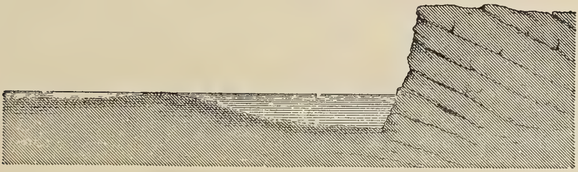
Fig. 165.—Middle Course of the Volga.

into steppe-land. On the east, the plains once washed by the river are scarcely raised above the average level of the water: during inundations they are converted into perfect seas; therefore the people have not been able to build more than three towns on the eastern bank. One of these towns—Kasan—was once situated at the confluence of the Kasanka and the Volga, but is now two miles from the latter river; it has, so to speak, travelled to the east. In Siberia the watercourses move to the right still more rapidly. The modern towns of Yakutsk, Tobolsk, Semipalatinsk, and Narym have already been partially rebuilt. Along these watercourses,

the right bank, which is undermined by the current, is almost invariably higher than the left bank bordering on the *toundras*, which once served as the bed of the river. This is a fact of such a general nature, that map-designers admit it as an axiom, and never fail to draw the right bank as being the highest and the most escarped. In the territory of Alaska also the right bank of the Yucon is the highest.

A large number of rapids and cataracts—among others, the magnificent falls of Trolhäta—also affords examples of a continuous displacement produced by the rotation of the globe. Similar phenomena are likewise observed in those river-like arms of the sea which are formed by the sea-water passing through a narrow channel; thus the force of the current is exercised mostly on the right-hand side in the Straits of Kertch and the Bosphorus, and the greatest amount of erosion takes place on this side. The law is of general effect, and applies to all the rivers which flow on the surface of the earth. The great rushes of water in former geological periods have likewise in their flow worn away the ground on the right-hand side. In the north of the Pyrenees, the *gaves*, which radiate so remarkably round the plateaux of Lourdes and Lannemezan, all flow through valleys of erosion,

Fig. 166.—Left and Right River-banks.



commanded on the east by high cliffs worn away at their base, and on the west by long slopes of easy access, on which the *débris* are deposited.

Among the important rivers which, in consequence of local circumstances, seem to contradict this law of the displacement of running water, we may mention the Mississippi and the Rhone. Instead of gaining on its right bank, and eroding the base of the heights which rise on the west, the great American river impinges in fifteen places against the cliffs of the eastern plateau, and, throughout the whole of its course, constantly tends towards the left. As soon as it enters the marshy plain of its delta at a point below Bâton Rouge, it flows almost in a straight line towards the south-east, to form the remarkable peninsula of mud through which it falls into the sea. It must be remarked, that the direction taken by the water of the current of the Mississippi is exactly the same as that of all the rivers which run into the Gulf of Mexico—the Rio Grande and its affluents, the Rio Pecos, the Nueces, the Colorado of Texas, the Brazos, the Trinity, the Neches: these rivers, which uniformly tend towards the south-east, are parallel to the ridges of the Rocky Mountains. If it is a fact, as many geologists seem to have established, that the western chains of North America are undergoing a movement of upheaval, whilst the Carolinas, Georgia, and other neighbouring regions are gradually subsiding, it might very well be the case that the lower course of the Mississippi and all the Texan rivers tend to the east, in consequence of the slow movements of elevation and depression to which the North American continent is subjected.

With regard to the Rhone, the mouth of which likewise flows in a south-east

direction, instead of tending to the right, as it once did, and following the vast bed now adopted by the smaller Rhone, it is possible that its course may have been modified during historic periods by the impetuosity of the *Mistral.* However strange an assertion of this kind may appear at first sight, it perhaps merits the attention of geographers. In fact, it seems a matter beyond all doubt that, in consequence of the gradual cutting down of the woods of the Cevennes and the central plateau of France, the *Mistral* has continued to increase in violence since the ages of the Roman occupation. If this be so, this turbulent wind must necessarily impel the waters of the Rhone towards the left bank in the direction they are taking at the present day. The aerial current beating down from the Cevennes on the marshes of the Camargue must necessarily have pressed upon the current of the river, and marked out for it the line which it had to follow in hollowing out for itself a fresh bed. Everything in nature takes its share in effecting modifications; every feature in the planet owes its form to the breath of the winds, the currents of the waters, and the movements of the soil, quite as much as to the motion of the globe in space.

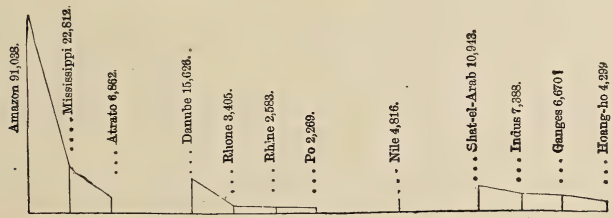
Rivers, taken as a whole, being merely the arterial system of continents, renewing the liquid mass of the seas, whence the waters return again to the interior of the land in the form of clouds and rain, it is important to know, at least approximately, the quantity of river-water which is flowing on the surface of the globe. For many years back various hypotheses have been regarded on this point; but any very precise data are still wanting, and nothing but observations taken for a series of years will render it possible to arrive at any accurate knowledge of this hydrological fact, so important in the economy of the globe. Buffon supposed that the mass of water emptied out by the whole of the rivers running into the sea would represent, in 812 years, a quantity of water equal to that of the ocean; but the data on which he based his supposition are not of sufficient authority to render it of much use to discuss his opinion at the present day. Among the most important calculations which have been recently made, taking as their starting-point the quantity of rain falling annually on the earth, we must mention that of Metcalfe. He estimates the total mass of water brought down by the rivers at 176,000,000,000 of cubic yards of water every day. Keith Johnston considers that the daily average discharge of the rivers of the earth is 229,000,000,000 of cubic yards, or more than 2,620,000 cubic yards a second.

This estimate is certainly much too high, for, by adopting another method, more in conformity to the rules of direct observation, and consequently more scientific—that is, by adding up the masses of water rolled down by the rivers which have been already gauged in various parts of the world by engineers and geographers—we find that the total discharge of a collection of river-basins comprehending an area of 4,246,000 square miles does not exceed a little more than 72,000 cubic yards a second. Now, these basins, which are those of the principal rivers of Western Europe, including the Danube, as well as those of the Nile, the Shat-el-Arab, the Ganges, the Hoang-ho, the Mississippi, and the Atrato, form a tenth part of the terrestrial surface, the waters of which flow down to the ocean. If, therefore, the proportion of water which runs from the surface of the ground into the sea were everywhere the same, the liquid mass of fresh water combining with the salt waves would not be more than 850,000 cubic yards a second. We must, however, take into account the enormous quantity of water discharged by certain rivers in the tropical zone, and especially the Amazon, the delivery of which is probably 100,000 to 130,000 cubic yards. If, therefore, we add a third to the

total river-discharge obtained by the previous calculations, we shall have for the whole mass a maximum of over 1,100,000 cubic yards a second. This is a quantity which represents an average fall of about 11 inches of rain over the entire surface of each basin, an average much larger than that of most of the rivers which have been studied up to the present time. If we admit that the average depth of the seas is 5,400 yards, the quantity of water which flows down the surface rivers of the Continent would not equal that which fills up the abysses of the ocean until after a lapse of about 5,500,000 years.

This is evidently nothing but a provisional calculation, which will be gradually rectified as the facts relative to the hydrology of the globe become better known. When the mean discharge of all visible watercourses is accurately gauged, when the force of subterranean streams has been disclosed by the investigations of meteorologists as to the fall and evaporation of rain, then it will be more easy to calculate, within a few millions, the total mass of liquid which is annually poured into the sea by the rivers of the continents. No doubt, within a period not very distant,

Fig. 167.—Diagram showing the Comparative Discharge of Rivers, in Cubic Yards.



the measures which have been adopted with so much precision as regards the Mississippi, the Po, the Rhone, and the Nile, will be applied with equal care to other river-mouths.

The investigations which have been simultaneously made as to the proportion of sediment which exists in suspension in rivers will enable us also to resolve the often-discussed question as to the actual importance of the alluvium of rivers. Without mentioning here the streams which are literally liquid mud, or sometimes even avalanches of mud, there are some rivers like the Missouri, the waters of which are so charged with sediment, that the drift-wood, being completely penetrated with muddy particles, is ultimately entirely submerged, and covers the bottom of the river. There are, on the contrary, other rivers, such as the St. Lawrence, which send down to the ocean water which is generally pure and transparent. During floods the Durance holds in suspension as much as 21 thousandths of mud; the Garrone sometimes contains 10 thousandths; the Rhine 6 thousandths only. It will be readily understood that the quantity of alluvium held in suspension must necessarily vary in different rivers, according to the more or less compact nature of the soils through which they pass; thus, observations made on any particular watercourse have nothing more than a local value. The estimations made by various geographers as to the average quantity of alluvium contained in running water differ prodigiously one from another. In the last century, Eustache Manfredi, who, taking account of the enormous deposits produced by the Po, exaggerated the work of this kind accomplished by other rivers, estimated the

average proportion of muddy matter at $\frac{1}{175}$ of the liquid mass of rivers. But in this estimate he doubtless included the sand and mud which are impelled by the current along the bottom of the bed, the bulk of which is probably twice as large as that of the floating matter. Hartsoeker, in his *Traité de Physique,* admitted that the proportion of alluvium was $\frac{1}{100}$; whilst another author of the same epoch, the writer of the *Recherches Philosophiques sur les Américains,* was led by his observations and calculations to fix the amount of *débris* existing in the water of rivers at only $\frac{1}{51080}$. Spread evenly over the bed of the ocean, it would form a deposit of less than half an inch in 341 years, or 40 inches in as many centuries, a result differing little from that arrived at by Croll.

The differences between the various estimates are naturally quite as great when an endeavour is made to reckon approximately the time that it would take for the alluvium emptied out at the mouths of rivers to raise the level of the ocean to a given point. Manfredi supposes that the detritus carried down to the sea would be sufficient to raise its bed a yard in 3,300 years. Tyler thinks himself warranted, by his calculations as to the alluvium of the Mississippi, in asserting that the deposits of rivers would elevate the level of the ocean only 2 inches in 10,000 years, or about a yard in 180,000 years. These are estimates of a very different character; but when one reflects on the greatness of the sea, and on the littleness of rivers compared with the immense reservoir, even the last-named estimate seems too high. If we admit that the average proportion of the earthy matter carried down into the sea is about $\frac{1}{3000}$ of the entire liquid mass of rivers, and if we adopt, as the total discharge of running water, the approximate quantity to which the critical examination of the known facts of fluviatile hydrography has led us, we shall find that the mass of alluvium deposited every second at the mouths of rivers would be equivalent in bulk to 436 cubic yards, or every year a body of matter equal to 4,000 square miles in area and a yard thick. This, however, would be an almost infinitesimal quantity in comparison with the enormous abysses of the ocean.

Yet the earth belongs to all time, and during the course of ages any geological work must ultimately be accomplished. These rivers, almost imperceptible, so to speak, in comparison with the ocean, are gradually eating away mountains and plateaux, and filling up the abysses of the sea with their accumulated *débris.* These deposits have the effect of raising the average level of the waters of the ocean, and of causing them to cover low shores. There is, therefore, a double cause operating in the modification of the relief and outline of continental masses If the only force in action on the surface of the globe was that of running water, the elevated parts of the earth would be constantly becoming lower, the sea would incessantly encroach on the coasts, and, sooner or later, the planet would become an immense globe, covered with a thin sheet of water. Owing, however, to the geological movements of the earth's strata, a transformation of this kind is not to be dreaded; but still, from the action of the water of rivers, continents and seas are undergoing changes of the very highest geographical importance. The Baltic Sea has already become something between an inland sea and a chain of fresh-water lakes. The liquid mass poured into it by rivers continues always the same, whilst the area and depth of its basin are constantly diminishing. In the long course of ages, its water will ultimately become perfectly fresh, and the Straits of the Sound will be merely a second St. Lawrence.

Some day, Bory de Saint-Vincent tells us, the Mediterranean itself will become nothing more than a chain of lakes, and then a gigantic river. The Sea of Azof is already being gradually converted into a stream, as its shores are getting nearer

and nearer together, whilst its bed remains perceptibly the same. The tracts of water which extend from the mouth of the Don to the straits of the Dardanelles might be compared to the Lakes Superior, Huron, and Michigan; the isles of the Archipelago will some day overlook a labyrinth of lagoons similar to those which border the Baltic Sea; the Gulf of Venice will be only an elongation of the valley of the Po; and the two great basins of the Mediterranean, separated by the Siculo-African bar, will become two lakes of increasingly contracted dimensions, the waters of which will feed the greatest river in the world. Then the Dnieper, the Danube, and the Po will be but mere tributaries. Perhaps even the Nile, which is now of no great size at its mouth, may lose all its water by means of evaporation before it reaches the Mediterranean Sea, and will become nothing but a watercourse of an entirely continental character, such as the Shary, the Hawash, and the Jordan.

Certainly it would be difficult to exaggerate the importance of the part played by rivers in the history both of the earth and mankind. They distribute uniformly the snow and rain which fall at the various points of their basins, and fertilise the whole territories by their innumerable ramifications. They powder up the rocks of the mountains, and spread the matter which results in fertile alluvium over the plains, forming, also, new tracts of land at their mouths. They equalise climates. Rivers coming from the south warm with their vapour northern districts, whilst rivers flowing in a contrary direction moderate the heat in more southern latitudes. Added to this, watercourses, those powerful workers, do not limit themselves to carrying down water, alluvium, and climate; they also roll down in their flow the history and life of nations. The course of the river's current is the path down which descended the canoe of the savage warrior, and is now the highway for the fleets of commerce bearing peace and comfort. Steam has converted rivers into roads, which can be traversed both in a downward and upward direction, and a floating population is constantly pervading their surface. Far from forming a barrier to nations, rivers are the means of mobilising them: they are continents set in motion. Aided by rivers, the mountaineers of the Alps and Pyrenees make their way to the Atlantic and the Mediterranean, whilst the inhabitants of the sea-coast ascend to the elevated districts in the interior of the continent.

CHAPTER LVI.

LAKES.—FORMATION OF LAKES.—THEIR INCREASE AND DIMINUTION.—THEIR FORM AND THEIR DEPTH.—LAKES LYING IN SUCCESSIVE GRADATIONS OF ELEVATION.

COLLECTIONS of water—ponds, pools, lakes, or inland seas—are formed in every depression of the ground which receives a larger quantity of liquid, either from rivers or directly from the clouds, than it can get rid of through its affluents, or transfer to the atmosphere in the form of vapour. Hence arises that infinite variety of lacustrine sheets of water which gives so much grace or grandeur to landscapes, and exercises such a considerable influence on the action of rivers, on climates, on the productions of the soil, and consequently on the development of mankind.

The liquid mass contained in any basin on the surface of the earth does not increase to an indefinite extent, even when considerable quantities of water are constantly being poured into it by its tributaries. Either the basin completely fills up, and the overflow is emptied out through the lowest depression in its rim, or the lacustrine sheet, gradually enlarging in area, ultimately presents a surface sufficiently extensive for evaporation to establish an equipoise to the supply of water.

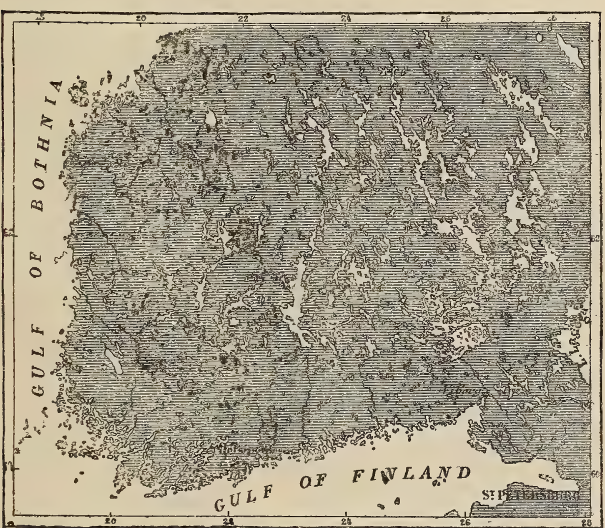
Perfect equality between the mass of water received and that which escapes does not, however, exist in any lake, and consequently the level never ceases to fluctuate; sometimes it rises and sometimes it sinks, according to the various seasons and years. After heavy falls of rain, or at the time of the melting of the snow, some pools are changed into perfect lakes, in the same way as, during long periods of drought, some lacustrine basins entirely dry up. The great phenomena of the vitality of the globe—such as the upheavals and sinkings of the ground, the growth of mountain ridges, the encroachments or retirement of the shores of continents, the alternations of the winds and rains, land-slips, and the rupture of natural dykes—all have the effect of either giving rise to and increasing, or of doing away with or diminishing, the masses of water which are collected in the interior of continents. Like everything else which exists on the surface of the globe, lakes have their periods of increase and decrease, and even within the limited period during which man has begun to record the annals of his planet, numbers of fresh lakes have made their appearance, whilst many others have entirely dried up, or have considerably diminished in extent.

In mountainous regions it is a well-known fact that the fall of rocks and the advance of glaciers have often caused the formation of considerable lakes. In like

manner, some of the large lakes of the Landes have appeared since the Middle Ages, owing to the cutting down of the trees upon the dunes, and the shifting of the latter towards the east. On the other hand, instances of lakes which have disappeared owing to natural causes, without being subjected to any human labour in the process of their exhaustion, are likewise very numerous.

Thus the plain of Oisans, in the Alps of Dauphiny, having been suddenly closed up in 1181 by a downfall of rocks which came from the sides of the Voudène, the waters of the Romanche, the Olle, and the Vénéon accumulated above the obstacle, and spread out into a lake of 6½ miles in length. Villages, vast plains, and whole forests were swallowed up under a liquid sheet of an average depth of 33 feet, and the local employment gradually became that of fishing. The lake existed for thirty-eight years, and then the barrier of *débris*

Fig. 168.—Lakes of Finland.



suddenly yielded under the pressure of the water, and the body of liquid rushed like a deluge over Grenoble and all the towns and plains on the banks of the Isère. At the commencement of the fourteenth century the former lake, which had received the name of the Lake of Saint-Laurent, was completely dried up.

The formation of lakes of this kind above some dam of rubbish, and their sudden disappearance when these dams are broken down, may, however, be considered as accidental phenomena, and not dependent directly upon climate. In this latter respect, the changes in level which are exhibited by some great lacustrine sheets, such as Lakes Titicaca and Van, are much more remarkable facts. Travellers assert that the area of the immense Bolivian lake has been constantly diminishing since the commencement of the historical period. Its water once bathed the walls of Tia-Huanacu, one of the principal cities of the Incas; but this

locality is now situated $12\frac{1}{2}$ miles from the lake, and more than 130 feet above the level of its water. This would be a remarkable proof of the increase of dryness on the high plateau of Bolivia. On the other hand, the height of the Lake of Van continues to increase—a fact which is confirmed by travellers every year. The inhabitants on its shores are frequently obliged to turn the coast roads farther inland; ancient villages have been swallowed up, and in some spots the ruins buried by the water are still visible. Finally, the town of Erjish, which was once separated from the lake by a great plain, is nowadays invaded by the water; and the city of Van itself, which was once far from the shore, is now quite close to it.

Fig. 169.—The Dombes in 1840.

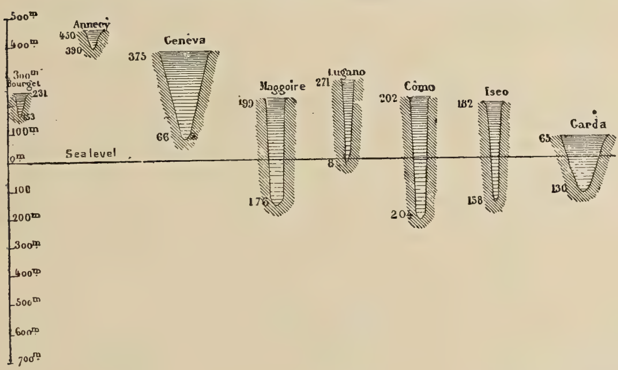
A legend, which explains in its own way the constant swelling of the water, relates that some capricious nomads having obstructed an outflow of the lake, afterwards made useless efforts to re-establish the former outlet; but, since this date, the irritated lake has never left off covering a fresh extent of plain every year.

As a simple process of reasoning must point out, lakes are most numerous and most extensive in those countries where rain falls in considerable quantities, and the surface of which, although but slightly undulated, is nevertheless formed of compact rocks which do not allow the water to flow away into the depths below, and retain it as if in natural basins. Such are the regions of North America,

in which lies the fresh-water Mediterranean crossed by the St. Lawrence, the Winnipeg, Winnipegoos, Bear and Slave Lakes, and several other sheets of water of less extent. In these districts there is certainly less rain than in the tropical zone, and even than in most of the countries of the temperate zone; for the depth of rain and snow-water does not attain to more than three feet in a year, But the granitic soil retains in the shallower depressions the moisture which falls from the atmosphere; evaporation does not take place actively, and the slopes towards the different seas are not sufficiently inclined for the numerous rivers to be able to pour down to the ocean all the surplus waters.

The island of Newfoundland is also in great part granitic, and is likewise covered by lakes maintained by the constant humidity which prevails in those parts of the sea. In like manner, in Europe, the eastern valleys of the Scandinavian mountains and the plains of Sweden exhibit a perfect labyrinth of lakes, some of which are very small, whilst others stretch away and are lost on the distant horizon, save where they are dotted over with archipelagoes, rocks, and islets, like Lake Malar, which contains no less than 1,260 islands. On the other

Fig. 170.—Altitudes and Depths of Lakes in Italy and Savoy.



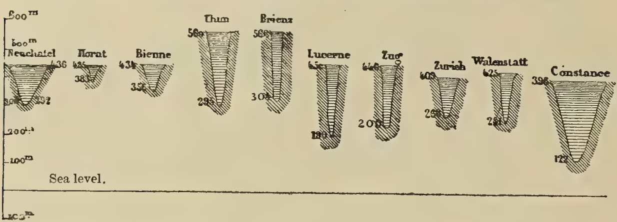
side of the Gulf of Bothnia, the granite plains of Finland are even still more densely studded with lakes, so that the whole country may be considered as an immense sheet of water intersected by innumerable isthmuses crossing one another in every direction.

Labyrinths of lakes of an altogether similar character are also found in countries where the soil, although not rocky, lies on a clayey or ochreous subsoil, which is entirely impervious to water. Thus, there used to exist in the French *landes* a great number of pools which the bed of *alios* retained on the surface; these are at the present time mostly dried up. In the same way Sologne, Brenne, and some other solitudes in central France, were dotted over with shallow pieces of water. La Dombes, a plateau of about 300 feet in height, which extends to the north-east of Lyons, between the Rhone, the Saone, the Veyle, and the Ain, is also covered with a multitude of pools, occupying altogether an area of more than 47,000 acres. It is a fact, that in this part of France man has unfortunately lent his aid to the work of nature. Most of the pools of the Dombes are of artificial origin, and

their being laid dry would cost even less than their construction. They serve as fish-ponds for the wretched inhabitants of the neighbouring villages, and then, being emptied and cultivated for cereals, they are again filled up and stocked with fish.

The form of a lake always bears some relation to the general relief of the ground in the depression of which its water is contained; its outline and the profile of its bed harmonise perfectly with the continental architecture. The water of alluvial, oozy soil, is spread out in vast marshes, in which it is difficult to point out the precise spot where the dry ground ends and the water begins. The liquid sheets of low plains, deserts, and level plateaux present generally more sharply defined outlines; but their depth is but slight in comparison to their extent, and the least fluctuation in level considerably modifies the line of their banks. The lakes of more undulating regions are in general tolerably deep in proportion to their extent, and present bays and promontories of a more varied and picturesque character than the sheets of water in the plains. But the place where lakes exhibit all their beauty is round the bases of lofty mountains. There, torrents run down into them, falling over in rapids and cascades; green glens slope down to their very margin; the spurs of the mountain plunge straight down

Fig. 171.—Altitudes and Depths of Lakes in North Switzerland.

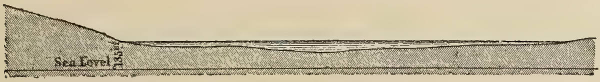


into their waters, and the shores between the headlands are traced out in gracefully curved bays. By the harmony and variety of lines presented by their outline, these lakes seem almost a necessary feature of the landscape, and their horizontal surface, by the contrast which it affords, gives a more noble appearance to the surrounding mountains.

Lakes, like seas, are in general all the deeper as the cliffs which overhang them are the more steeply escarped; indeed the cavities which are filled up by the water seem to correspond in their dimensions to the height of the upheaved masses. Thus, to bring forward no other instances than those of the Alpine lakes, the deepest of these lakes are found at the southern base of the Alps, which on this side present their steepest slopes. Lake Maggiore, the level of which is 652 feet above the Adriatic, is no less than 2,800 feet in depth; the Lake Como is 1,981 feet deep in the lowest part of its basin. The Lakes of Garda and Iseo are not so deep, but still deep enough to descend far below the level of the sea. If we could suppose the whole body of the Alps cut down to the level of the sea, the abysses of the water in the Lakes of Maggiore, Como, Garda, and Iseo would still be respectively 2,149, 1,318, 518, and 426 feet in depth; whilst, on the other side of the Alps, the only lake which has a bed below the level of the sea-water is, perhaps, that of Brienz, if it be true, as Saussure asserts, that it is 1,968 feet in depth. The two annexed plates represent the respective altitudes of the principal lakes of the

Central Alps in comparison with the level of the sea. The results depicted in these plates have, however, unfortunately only an approximate value; for in the Alps, which are, nevertheless, visited and studied by so many scientific men, accurate sounding operations have not yet been made in some of the most important lakes. In each of these plates the depth has been exaggerated a hundred-fold in comparison with the breadth. In order that a clear idea may be formed of the shape of the Alpine lakes, it is necessary to annex here the actual outline of the depression of Lake Maggiore, the deepest of all the lacustrine basins in the Alps, and of the Lake of Neuchâtel, the principal sheet of water in the Jura. But it must also be considered that the bed of most lakes is almost perfectly horizontal, often revealing to the sounding-line scarcely a few inches of difference over wide areas. This is

Fig. 172.—Lake of Neuchâtel.



due either to the sedimentary matter uniformly spread over the bottom, or to the previous formation of these depressions, which afterwards become flooded basins. Remarkable instances of this formation are the Lake of Geneva, west of Vevey, and the Gulf of Uri in the Lake of Lucerne.

Glancing at a map of the Alps, it is impossible to avoid remarking at first sight that the lakes are distributed in a certain order as regards the great groups of mountains. Thus the Maritime Alps, those of Viso, Provence, and Dauphiny, and also the Mont-Blanc group, have but a very small number of lakes, and even these better deserve the name of ponds. On the east of Switzerland the various ranges of the Alps, which extend as far as Turkey, are likewise almost devoid of lakes, except in Southern Bavaria and the districts of Salzburg, where several masses of

Fig. 173.—Valley.

Fig. 174.—Cluse.

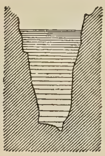
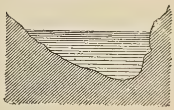


Fig. 175.—Combe.



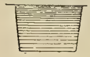
water fill up some narrow valleys which open nearly uniformly from south to north between parallel chains of mountains. The noble lakes which form the glory of the Alps are all situated round the central group (of which the Saint-Gothard occupies the middle), and in the valleys and plains which, under various names, form the western limit of the parallel ridges of the Jura.

These lakes, which evidently owe their origin to the star-like form of the chains which radiate round the Saint-Gothard, and to the intersection of the Alpine system by that of the Jura, have in general elongated basins, tending either from south-west to north-east, or, perpendicularly to this direction, from south-east to north-west. The waters of the valleys of the Jura—for instance, the Lakes of Joux and Saint-Point—lie in the former direction, likewise the great bodies of water situated at the base of the limestone mountains—the Lakes of Neuchâtel,

Bienne, and Morat. The Alpine lakes of Brienz, Sarnen, and those of Engadine also lie in this direction; and even the lakes on the Italian side, Maggiore and Garda, are nearly parallel to the lacustrine basins and mountainous ridges of the Jura. On the other hand, the great Alpine lakes of Constance, Zurich, Sempach, Zug, and Thun, all stretch in a contrary direction to those above named. With regard to the two magnificent inland seas of Switzerland, the Lakes of Geneva and Lucerne, they owe their admirable shape to a combination of the two types. The Leman is a lake of the Jura in its lower part, and an Alpine lake in its upper part; towards the middle the two sheets meet and cross one another. In the Lake of Lucerne the two basins cross one another at right angles, and thus give to the whole body of water the shape of a cross.

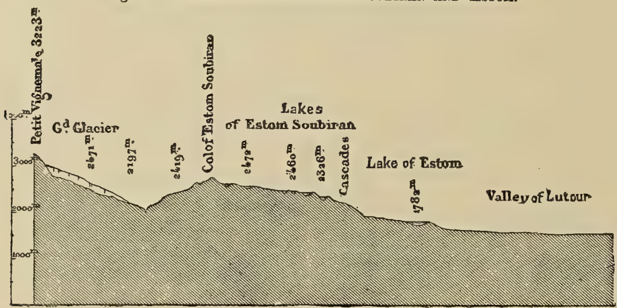
Fig. 176.—Transverse Section of Lake Geneva.

Scale of breadth, 1 : 640,000.
„ depth, 1 : 32,000.



It must likewise be remarked that the largest lakes are found on the courses of the most plentiful rivers, which goes to prove that the same geological laws have presided in the formation of the valleys and in hollowing out the lacustrine basins. The Lake of Constance, the largest of all, receives the Rhine, the largest river in

Fig. 177.—Lake-stages of Estom Soubiran and Estom.



Switzerland. The Leman is crossed by the Rhone; the Aar flows into the two Lakes of Brienz and Thun; the Reuss enters the Lake of Lucerne, the Linth that of Zurich. An arrangement of this kind can hardly be fortuitous, but must depend on the general structure of the great groups of the Alps.

In those mountains which possess an architecture of almost perfect regularity, as, for instance, those of the Jura, it is easy to classify the various lakes according to the form of the depression which is filled by their waters. Thus the lacustrine sheets which spread out in a valley between two parallel ridges of mountains generally exhibit outlines which are scarcely at all broken and disposed in a regular oval; the slopes of the bed are gently inclined towards the central part, the average depth of which is not, however, very great. Here and there, and especially at the two ends, the banks are marshy, and it is difficult to determine the exact spot at which the firm ground begins. Among these valley lakes we may mention those of Joux, Saint-Point, and Bourget.

In a similar way the *combes* and *cluses*, which serve as reservoirs to the lakes, confer on the water which they contain special characteristics very different from those of the lacustrine basins in valleys. Thus the lakes in *cluses*, lying crosswise

$\frac{1}{365\,000}$

Kilometres

5 10

to a chain of limestone mountains, are generally narrow, and the escarpments of the high cliffs which command them descend to a great depth below the surface of the water. With regard to the lakes in *combes*, the amphitheatre-like reservoirs which contain them give to the surroundings of each basin a magnificent aspect of grandeur and majesty. The water in them is deeper than that of the valley lakes,

Fig. 178.—Lakes of Nors Elf

but not so deep as that of the lakes in *cluses;* and it is just in the lower portion of the lacustrine cavity that the section of water presents the greatest thickness.

It is, however, but seldom that—in the Swiss Alps and other mountainous countries with a deeply indented vertical outline—we do not find lakes which present characteristics of all the different types. In some parts of their basins they

are lakes of the valley, and in others they are lakes like those contained in *cluses* or *combes*. For this reason what a diversity of appearance they present in their shores, what picturesque beauty in the windings of their bays and the succession of their headlands!

Between mountain ridges which are not arranged in long parallel lines like those of the Jura, valley lakes are not mere oval sheets of water; they extend in long windings like the Lakes Maggiore, Como, and Lugano; or in those valleys in which wide basins and contractions alternate in succession, the lakes spread out and become narrow alternately. Numerous instances of this may be seen in the Scandinavian mountains. In a general way, however, these lakes are cut up into several pieces of water lying in gradation, one above the other, as if on enormous steps, and are connected by narrow defiles, down which the water of a torrent pours in cascades. These lakes, lying on graduated levels, are found in the high valleys of almost every mountainous country. In Switzerland, the three lakes of Lungern, Sarnen, and Alpnach, which are traversed by the river Aar, may be mentioned; in the Pyrenees, the mountain lakes of Oo and La Têt, and the lakes of the valleys of Couplan, Aygues-Cluses, and Estom Soubiran belong to the same class of lacustrine basins. In the Carpathians they form those charming little pools of water to which the name of *meeraugen* (eyes of the sea) has been given; lastly, in Scandinavia, lakes situated on graduated levels may be reckoned by hundreds.

There, all the rivers, almost without exception, are, from their source to their mouth, nothing but chains of lakes connected with one another by rapids and cascades. They are, in fact, watercourses in process of formation, which have not as yet hollowed out for themselves regular beds, but flow in all the natural depressions of the soil through narrow channels which have been opened since the ground itself has risen above the level of the sea. The land of Scandinavia, having risen only at a recent epoch by a gradual movement of emergence, which at the present time is still continuing, the rivers have not yet had time either to fill up with *débris* the lakes that they meet with in their course, or to pierce wide valleys through the rocks.

CHAPTER LVII.

VARIOUS PHENOMENA IN LAKES.—COLOUR OF THEIR WATERS.—SEICHES.—CURRENTS AND TIDES.—FORMATION OF ICE IN LAKES.

LAKES are not only distinguished from each other by their shape and the depth of their basin; they also vary in the appearance of their water, and even in this respect the diversity of the matter held in suspension or solution in the liquid mass is not always sufficient to explain the remarkable contrast presented by adjacent sheets of water. The colour and transparency of the liquid differ astonishingly in most mountain lakes. Some are of an emerald green, others of a sapphire blue, a few even have a milky shade. There are some, indeed, the water of which is transparent, that have a brown or yellowish colour. In every case, whatever may be the natural hue of each of these lakes, they incessantly vary on account of the reflection of the rays of the sun, the clouds, or the colour of the sky and the refraction of the light. One lake, the water of which not far from the bank is of a yellowish green, owing to the rocky bottom just visible below the undulations of the surface, is of a deep blue above the invisible abysses of its central portion. Another lake presents a well-defined difference of colour between the tranquil water of its basin and that which is brought in by the rapid current of the river which crosses it. In other places, again, the eddies light up the surface with reflections of a bronzed or greenish hue; even the particles of sand or ooze, as well as the chemical substances dissolved in the water, must necessarily, however infinitesimal their tenuity may be, tinge the liquid sheets with various shades. Vegetable mould gives to lakes a colour more or less shaded with red or brown; clay gives them a yellowish tinge. As to the *débris* of rocks and pebbles, these, according to Tyndall, are the agents which confer on the Lake of Geneva and other mountain lakes their lovely azure colour. The most wonderfully transparent water, which, too, is the most devoid of all impurity, is in general a sea-green hue. It is said that objects are sometimes visible in it at a depth of 80 and even 100 feet.

All long and narrow lakes, over which atmospheric variations often take effect in a sudden and violent manner, frequently exhibit abrupt oscillations of level, which can only be explained by a difference in the pressure of the air. Such are the *seiches* of the Lake of Geneva and the *Ruhssen* of the Lake of Constance, which are noticed sometimes at one point, sometimes at another. In these purely local swellings of the water, the latter may rise all at once some inches, or even a yard, above the level of the surrounding surface. The outbreak of subterranean tributaries cannot be taken as an explanation of the cause of this sudden rise, for it takes place at the foot of mountains of a compact formation, which certainly do not conceal any considerable streams in the depths of their rocks. Added to this, on

the surface of many lakes and inland seas the phenomena of *seiches* have been observed around islets and mere rocks.

Schulten has proved that the *seiches* of the Baltic, which are in every respect similar to those of the Lake of Geneva, are in direct connection with the height of the barometrical column. When the pressure of the air diminishes the water begins to swell, and when the barometer again rises the surface of the sea sinks, only the movements of the water are always a few minutes earlier than those of the instrument, on account of the greater mobility of the aqueous particles. Now, as the total variation between the different heights of the barometrical column at the level of the sea corresponds to a variation of about a yard in a column of water, it follows that the most considerable *seiches* cannot exceed this height. This has, in fact, been verified by observers in the Baltic as well as in the Lake of Geneva and in the great lakes of North America. In the midst of the open sea *seiches* would likewise be produced, especially during hurricanes; but the liquid mass being at full liberty, and able to spread out freely all round the rising of the wave, the phenomenon is there more difficult to notice than in narrower lakes. It is probable that the phenomenon known by the Sicilians by the name of *marubia* (from *mare ebriaco*, "drunken sea") is also a swelling of the water accompanied by the barometrical depression. It is observed on all the coasts of Sicily, but especially off Mazzara, at the precise spot where the Mediterranean, contracting into the form of a strait, is severed into two basins by a submarine ledge which approaches the surface. Daubeny considers that these movements of water are a sign of some volcanic vibration of the soil; yet the description which he himself gives of the movements seems to indicate that they are *seiches* similar to those in the Lake of Geneva and the Baltic. When the *marubia* occurs the air is calm and the horizon misty; suddenly the water, stirred up in short waves, raises its level about 23 inches, and then, after an interval of from half an hour to two hours, the south wind begins to blow, and a heavy storm rises. To the phenomenon of the seiches M. Forel also refers the remarkable tidal currents of the Euripas, betweeen Attica and the island of Eubœa.

Lakes, moreover, which are, indeed, inland seas of fresh or salt water, must exhibit phenomena similar to those of the ocean. Lacustrine sheets of water have also their tempests, their swells, their breakers, and their bores; and certain bays of Lakes Superior, Ladoga, and Baikal, are not less dangerous than the Black Sea and the Bay of Biscay. The waves raised by the wind in the more confined areas of lakes are neither so high nor so rapid as those of the sea, because they have not so vast a field on which they can spread out, and because they do not move over a sufficiently great depth of water. They are short, compact, and "chopping," and from this very fact they are more formidable to any ship against which they incessantly dash. Added to this, the water of most lakes being fresh, and in consequence lighter than that of the ocean, it is also more readily stirred up, and the wind has scarcely commenced to blow before the surface of the lake is roughened with foaming billows.

One of the most curious phenomena in the lakes of the northern temperate and polar zones is that of the formation of ice. In winter, when the sheet of water is perfectly still, needles of ice, radiating one from the other at angles of from 60 to 120 degrees, appear on the surface; then joining their network together, they soon form a level sheet of ice. On the contrary, when the water is violently agitated by a storm, the first needles of ice being incessantly bruised and rubbed against each other, agglomerate in discs rounded by the friction, and the whole of

the congealed mass ultimately presents an uneven surface, like that of rivers with a rapid and violent current. The ice of lakes is generally much more regular and transparent than that of watercourses, in which the process of crystallisation is nearly always being disturbed.

In the great lakes of North America, and also in those of Siberia, especially in Lake Baikal, the phenomenon of the formation of ice takes place in the most magnificent way. During three months of winter, the mighty Baikal, the inland sea in which seals live and coral-stems grow as in the ocean, is covered by a field of ice, presenting in some places a thickness of 6 to 9 feet. The vast sheet of water, extending over an area of more than 1,400 square miles, and surrounded by mountains as high as the Alps, and glittering with glaciers, is nothing but a solid mass, on which caravans of travellers venture without fear. Sometimes, when the ice begins to form, a sudden tempest reduces it to fragments, which, under the pressure of fresh pieces of ice, brought by the waves and currents, are piled up one on the other, intermingling in a kind of chaos which calls to mind the *séracs* of the Alpine glaciers. Subsequently, when the water is entirely covered with its heavy shell, the latter is occasionally rent asunder, and shrill whistlings, dull cracking noises, prolonged thunder-like rumblings, mingled with innumerable partial crepitations, are heard whilst the ice is bending and breaking. The water springs out from the fissure in vertical sheets, and falling down again on the surface, forms risings on each side of the crack, which is sometimes more than a yard wide. Sometimes, a fragment of the broken layer of ice sinks below the general level; another piece, being pressed on in every direction by the frozen masses, curves perceptibly in the middle. All these movements of the solid crust produce long undulations in the water beneath. Travellers, borne along rapidly in their sledges over the ice of the lake, feel distinctly the shock of the waves breaking against the under surface of the trembling floor beneath them. On the sides of the cliffs which border on the lake may be noticed heaps of solidified flakes, sometimes resembling a cascade; this is the foam which is jetted out at the time of the violent rupture of the ice, and has hardened upon the rocks before it had time to fall. In a general way, Lake Baikal freezes so rapidly that, according to the statement of the natives, the ice begins by adhering to the bottom of the lake, from which it afterwards becomes detached with a terrible noise and rises to the surface. But this fact, which could not take place unless the temperature of the deep water was much lower than that of the surface which is traversed by freezing winds, has not yet been scientifically verified. It is, on the contrary, very probable that the water on the bottom remains constantly liquid. At the temperature of 39° F. the aqueous particles acquire their greatest density, and consequently their heaviest specific gravity. In obedience to the law of gravity, the layers which are at 39° F. of temperature are those which must lie upon the bottom of the lake, and therefore ice can only be formed on the surface. The direct observations which have been made as to the temperature of the Swiss lakes confirm this theory. In the Lake of Geneva, the effects of meteorological variations are not felt below a depth of 236 feet, and deeper still the constant temperature is 42° F. In the Lake of Constance, the temperature is lower; there it is only 39° F., and in the Lake of Lausanne, 39° 12′ F.; this comparatively slight excess of heat is probably owing to the natural warmth of the ground. Added to this, in the environs of Boston, where all the small lakes are regularly worked during winter, and furnish for the demands of commerce more than 200,000 tons of ice a year, the solid layer of ice has never been noticed to form in the first place at the bottom of the basin.

CHAPTER LVIII.

LAKES ACTING AS REGULATORS OF THE RIVERS WHICH PASS THROUGH THEM—FRESH-WATER AND SALT-WATER LAKES.—THE CASPIAN SEA.

THOSE lakes which receive a superabundant quantity of water—and these constitute the most numerous class—give rise to a river which carries off the surplus of the liquid mass poured into the basin by the upper affluents. These lacustrine reservoirs may then be considered as expansions to some extent of the fluviatile valley; in this point of view, the Lake of Geneva would be the Rhone, and become a hundred times wider and deeper. The Lake of Constance would be an immense hollow of the Rhine, containing in its reservoir nearly a hundred times as much water as all the rest of the river. In like manner, the great inland lakes of North America—Superior, Michigan, Huron, Erie, and Ontario—form the first part of the course of the St. Lawrence, a river of such slight importance in comparison to the vast basins which feed it.

The large basins in which the water of a river is spread out, before it again takes its course down to the ocean, regulate the discharge of their outflows all the more efficiently the more extensive the area over which they extend. Very considerable inundations in a stream produce comparatively but a slight rise in the level of a lake, because the water has to be diffused over the whole surface of the basin, and loses in depth all that it gains in breadth. During the season when the ice is melting—that is, in spring and summer—the Lake of Geneva rises on the average 6 feet above the low-water of winter, and consequently contains a surplus mass of 1,572,000,000 cubic yards of water. The gauges used at Geneva establish the fact that the discharge of the Rhone at its issue from the lake is at its maximum 753 cubic yards. Now, as the various affluents of the lake supply more than 1,400 cubic yards during their highest floods, it is evident that the Lake of Geneva acts as a complete regulator. It keeps back at least one-half of the inundation-water, which it subsequently empties down gradually when its tributaries have retired to their usual level. It is certain that, owing to the regulating action exercised over the discharge of the river, the plains on the banks of the middle course of the Rhone, from Geneva to Lyons, are comparatively protected against floods. The equilibrium in the action of the river would be still more complete if a dam were constructed at Geneva, with flood-gates to regulate at will the discharge of the water.

Lakes which are crossed by rivers must be, almost without exception, fresh-water-basins, as the saline particles which are carried into the basin by one or more affluents are conveyed out of it with the surplus water. Still, lakes of no great

area, which are mostly fed by salt springs, discharge brackish water through their outflows. As regards lakes without any outlet, it is evident that the saline particles brought into them by tributaries cannot make their escape, and must consequently be deposited on the edges, or must more and more saturate the liquid

Fig. 179.—Caspian Sea.

Scale 1 : 8,450,000.

mass. Unless they are fed by affluents entirely devoid of saline matter, lakes which are without any communication with the sea must, therefore, more or less resemble the ocean in the composition of their waters. Almost all the lakes without outlet are filled with water more or less saline. It must, however, be under-

stood, that the proportion of salt varies in all inland basins, and the transition is most gradual between the condition of water called fresh, and that of brackish or salt water.

The largest inland sea devoid of any outlet—the Caspian—is the remains of that great central sea which once extended from the Euxine to the Frozen Ocean. It is probable that the slow upheaval of Siberia and Tartary has gradually separated the Caspian from the Gulf of Obi and the Sea of Aral, and that, subsequently, the rupture of the Bosphorus, by lowering the level of the waters of the Black Sea, has laid dry the Ponto-Caspian isthmus, which is now traversed by the waters of the Manych. Be that as it may, it is certain that by remaining isolated in the middle of the land the Caspian has lost by evaporation a larger quantity of water than is supplied to it by its tributary rivers; for it has gradually diminished in extent, and its level has sunk more than 80 feet below that of the Black Sea. If the Caspian was again to fill up the whole concavity of its basin to a height corresponding to that of the adjacent open seas, it would inundate the whole plain of the Volga below Saratov, and would cover the surface of the steppes for an area of several hundred thousand square miles.

The Caspian Sea is divided into three distinct parts. The northern portion—the bottom of which continues the almost imperceptible slope of the steppe—is a vast marsh, which is nowhere more than 48 to 50 feet deep, which, too, several rivers are constantly engaged in filling up with their alluvium. In the southern part of this sea of steppes lies the central basin of the Caspian, which is bounded on the south by the promontory of Apsheron, a prolongation of the Caucasus. The southern basin, mostly surrounded by high mountains, the escarpments of which extend beneath the water, is also the deepest. In some spots soundings have been made of 1,772 and 2,953 feet.

The saltness of the water is very unequal in different parts of the Caspian. On the north, the Terek, the Ural, and especially the Volga, bring down to the sea an enormous liquid mass, so much so that the total saltness is only from 15 to 16 ten-thousandths, and at many of the post stations, where there is a deficiency of springs, they drink the sea-water without either dislike or danger. The central and southern basins, on the contrary, contain water which is completely salt. It is proved by the experiments of Baer that the average saltness is about nine-thousandths; this is a degree of saltness about one-third of that of the water of the Atlantic Ocean.

Is the saturation of the Caspian diminishing during the course of ages, or is it, on the contrary, in process of increase? At first sight one is tempted to admit the fact of the increase of the saltness as an evident matter, since the soil of the surrounding steppes is gradually yielding up to the sea the salt which it contains. The rain and snow-water, when penetrating through the surface layer of sand, carry with them the saline particles, and concentrate them in the clayey subsoil. In every place where the ground is hollowed out by the ravines, so numerous on the steppes, the saline clay is washed away by the water, and carries the matter with which it is charged into the Caspian Sea, either directly or through the bed of a river. It appears, then, that the waters of the Caspian ought to present an increasingly large proportion of salt.

Yet Baer, who has devoted more study to this inland sea than any other *savant*, does not believe in any increase in the degree of saltness in the waters of the Caspian; and, in his idea, if the proportion of salt be undergoing any change at all, it is diminution. In fact, in the plains abandoned by the sea, banks of shells

are here and there to be met with, which are identically similar to those of the shell-fish which now inhabit the Caspian. The dimensions of these shells, being always proportional to the quantity of salt contained in the water, ought to indicate the degree of saltness of the former sea, and thus give a point of comparison. Now the shells which are picked up in the vicinity of Lake Elton, more than 200 miles from the present sea-shore, are as large as those of the molluscs which now inhabit the open Caspian, at a point 60 miles from the mouth of the Volga. Near Astrakhan, where the sea-water, being mingled with that of the river, must be comparatively fresh, the shells left by the retirement of the sea indicate a degree of saltness equivalent to that of the water in the central basin. Moreover, in the environs of Baku, on the sides of the hills which overlook the water, amid the rocks, shells of molluscs are found which are much larger than those of the same species now inhabiting the sea some yards lower down. This fact alone is sufficient to afford considerable probability to Baer's hypothesis as to the decrease of saltness in the waters of the Caspian. The Black Sea, however, with which the great inland sea of Russia formerly communicated, contains proportionately twice the amount of salt.

How can this decrease be possible? How is it that the salt brought down by the rivers and outlets is able to escape from the vast basin which has received it, and to separate itself from the sea-water with which it is mingled? Nothing can be more simple; by the regular movements of its waves, the Caspian—like all other seas—throws up banks of sand in front of the shallow bays of its shores, and thus converts gulfs and creeks into lagoons, into which the sea-water runs only through a narrow channel. Evaporation, which is very active in these regions bordering on the burning desert, is constantly tending to sink the level of these basins, whilst the sea-water charged with salt flows in without intermission to maintain the equilibrium; in this way are formed perfect magazines of salt, which are incessantly being increased. When, after heavy storms or a long continuation of dry weather, the channel which communicates between the sea and the lagoon ultimately becomes dried up, the sheet of water, now completely isolated, diminishes rapidly in area, or is even completely absorbed by the atmosphere, nothing being left of it but a layer of salt of variable thickness, which is formed at the expense of the sea. Thus it is that the lagoons recover from the Caspian the salt which the rivers of the steppes carry down to it. The only question is to know if equality exists between the in-comings and the out-goings, or if, in conformity with M. de Baer's theory, the loss of salt is more considerable than the gain. A long series of accurate observations could alone solve this problem.

The formation of these saline reservoirs may be studied all round the circumference of the Caspian Sea. A former bay, situated not far from Novo-Petrosk, on the eastern coast, is nowadays divided into a large number of basins, which present every degree of saline concentration. One basin still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom hidden by a thick crust of rose-coloured crystals like a pavement of marble. A third exhibits a compact mass of salt, in which glitter here and there pools of water, situated more than a yard below the level of the sea. Lastly, another has lost by means of evaporation all the water which once filled it, and the strata of salt which carpet its bed are partly covered by sand. The same facts are found existing farther to the south, in the environs of the Bay of Alexander, and also quite at the extremity of the northern basin, at

the point where the arm of the sea lies which is known under the name of Karasu (black water). The saltness of the Karasu exceeds that of the Gulf of Suez, the saltest of all the seas which communicate with the ocean; in this part of the Caspian the proportion of marine salt rises to nearly 4 hundredths, and all the salts combined form 57 thousandths of the water; animal life, therefore, must there be almost if not entirely suppressed.

Among the thousands of bays and lagoons in which the salts of the Caspian are stored up, none is more remarkable than the Karaboghaz, a kind of inland sea which probably connected the Hyrcanian Sea with the Lake of Aral, and into which perhaps the Oxus emptied itself, if this river ever was a tributary of the Caspian. This vast gulf communicates with the sea by a narrow mouth, which, in its most contracted part is from 150 to 160 yards wide; the bar will not allow vessels to enter which draw more than 5 feet of water. A current coming from the open sea is always running through the strait with a speed of three knots an hour. The west winds accelerate it, and the winds which blow in an opposite direction retard it, but it never flows with less rapidity than a knot and a half. All the navigators of the Caspian, and all the Turkoman nomads who wander on its shores, have been struck with the unswerving, inexorable advance of this river of salt water, rolling over the shoals towards a gulf which even recently none had ever ventured to navigate. In the view of the natives this inland sea could be nothing but an abyss, a "black gulf," as is expressed by the name Karaboghaz, into which the waters of the Caspian dive down in order to flow through subterranean channels into the Persian Gulf or the Black Sea. It is perhaps to some vague rumours as to the existence of the Karaboghaz that we must attribute the statements of Aristotle about the strange gulfs in the Euxine, in which the waters of the Hyrcanian Sea bubble up after having flowed hundreds of miles through the realms of Pluto.

The existence of this current, which conveys the salt waves of the Caspian into the vast gulf of Karaboghaz, is nowadays most satisfactorily explained. In this basin, exposed as it is to every wind and the most intense summer heat, the evaporation is considerable; the water is, therefore, constantly diminishing, and the deficit can only be supplied by a continual fresh flow. Investigations, which can be readily made in the narrow and shallow channel of the Karaboghaz, have failed to ascertain the existence of a sub-marine counter-current conveying back to the Caspian the salter water of the gulf. It is, therefore, very probable that it is the atmosphere only which absorbs the water brought by the Caspian current; but though deprived of its water by evaporation, the immense marsh retains the salt; the saline matter is more concentrated in it, and the water is more and more saturated with it every day. Already, it is said, no animal can live in it; seals which used to frequent it are no longer found there, and even its banks are devoid of all vegetation. Layers of salt begin to be deposited on the mud at the bottom, and the sounding line, when scarcely out of the water, is covered with saline crystals. Baer has made the attempt to calculate approximately the quantity of salt of which the Caspian is every day deprived for the benefit of the "black gulf." Taking only the lowest estimates of the degree of saltness of the Caspian water, the width and depth of the channel, and the speed of the current, he has proved that the Karaboghaz receives daily 350,000 tons of salt—that is, as much as is consumed in the whole Russian empire during a period of six months. If, in consequence of violent storms, or the slow action of the sea, the bar should close up between the Caspian and the Karaboghaz, the latter would quickly diminish in extent; its

banks would be converted into immense fields of salt, and the sheet of water which might remain in the centre of the basin would become only a marsh. Perhaps, indeed, it would disappear altogether, like that sea which used to lie between Lake Elton and the River Ural, the former existence of which is made known only by a depression in the ground of about 79 feet below the level of the Caspian, and 151 feet below that of the Black Sea. Like a tree letting fall its fruit upon the ground, the Russian Mediterranean detaches from its bosom the bays and gulfs on its coasts, and scatters them over the steppe in the form of lakes and pools.

The comparative observations which have been made as to the average level of the Caspian Sea are not yet numerous enough to warrant us in admitting, with certain geographers, as a proved fact that there is a constant diminution of the water in this inland sea. We are likewise ignorant what foundation there may be for the opinion of some of the inhabitants of the coasts, mentioned by Humboldt in his *Asie Centrale*, according to which, the Caspian Sea experiences a succession of rises and falls every twenty-five to forty-five years. It seems, however, probable that the oscillations in its level are of no great importance, and that the quantity of water removed by evaporation is on the average exactly replaced by the liquid mass accruing from rivers and rain. An equilibrium is nearly established between the supply and the loss.

At the epoch when the Caspian Sea was separated from the Euxine, its level must have sunk in a comparatively rapid way through the excess of evaporation. A proof of this fact may be seen on the sides of the rocks which were once washed by the waves of the Caspian. At the height of 65 to 80 feet above the present level of the water, these former shoal-rocks have been furrowed out into tooth-shaped points and needles; lower down, on the contrary, the rocks bear no trace of the erosive action of the water, evidently because the level of the sea sank too rapidly to allow the waves sufficient time to attack successfully the cliff walls.

The innumerable indentations which cut into the shore between the mouths of the Kuma and those of the Ural, and principally south of the Volga, constitute another striking instance of the rapidity with which the level of the Caspian must have sunk after the sill of the Isthmus of Manych emerged from the water. For a space of more than 248 miles the shore is furrowed with very long and narrow channels, twelve, twenty, and even thirty miles in length, and throws out into the sea a multitude of peninsulas, which are prolonged for a great distance into the water by isles likewise disposed in parallel ranges and separated by long channels. These tongues of land form a kind of chain, which is interrupted here and there by the sea-water, and sink by successive falls from isle to islet, and from islet to marsh. The thousands of channels which separate these narrow embankments of land are an immense labyrinth, unexplored even by fishermen; it requires a map of the most detailed character to give any idea of this strange swarm of isles, islets, channels, and bays.

The *bugors* or chains of hillocks which run between the parallel bays, and farther inland are connected with the level ground of the steppes, are in general very narrow, their length varying from a hundred yards to three or even four miles. They usually rise to the unpretending elevation of 26 to 30 feet; but some attain double this height. Seen from a balloon, the *ensemble* of the *bugors* would resemble a tract of marshy land turned up by a gigantic ploughshare. Immediately to the west of the Volga, the *limans*, or furrows which separate the *bugors*, are always changed into rivers. During the inundation of the river, the current pours into these channels the overflow of its waters charged with mud; then, after the

flood is over, the sea again penetrates them, and there is thus produced in these channels a constant backward and forward motion between the sea and the Volga. Farther to the south, the narrow valleys of the *limans*, not being so often filled up by the flood-waters, do not in general present a continuous sheet of water, but only a chain of lakes, separated from each other by sandy isthmuses.

If we compare the whole of these ranges of hillocks to a border of fringe attached to the continent, we shall observe that these fringes spread out somewhat like a fan, on one side towards the north, on the other towards the south. They are all like the extremities of radii diverging from a common centre which would lie in the depression of Manych, on the ledge which separates the slopes of the two seas. How can this arrangement be explained, except by the fact of the rapid sinking of the level of the Caspian waters hollowing out in the soft soil the narrow furrows which so astonish us? Thus, on the muddy banks of a reservoir when the sluice-gate is opened, small *limans* are formed, separated by *bugors* in miniature. A very remarkable fact, which again tends to confirm the result of Baer's investigations, is that all the *bugors* of the Caspian shore are stratified, and the superimposed beds assume the form of concentric arches. The strata of the strongest clay are, as it were, the nuclei round which are deposited the earth that is more mingled with sand. This distribution of the strata is owing to the action of the currents of water which gave to the *bugors* their present appearance. It may, in fact, be readily understood that the strata of clay and sand, being undermined laterally by the water running down the channels, bent over on both sides towards the currents which washed their bases; hence arise these stratifications in the form of an arch.


45°
46°
Volga
ASTRAKHAN
46°
46°
STEPPES
Mouth of the Volga
CASPIAN SEA
45°
45°
Mouths of the Kouma
45°
46°
1
1.134.000
Kilometres.
0
10
25
50

CHAPTER LIX.

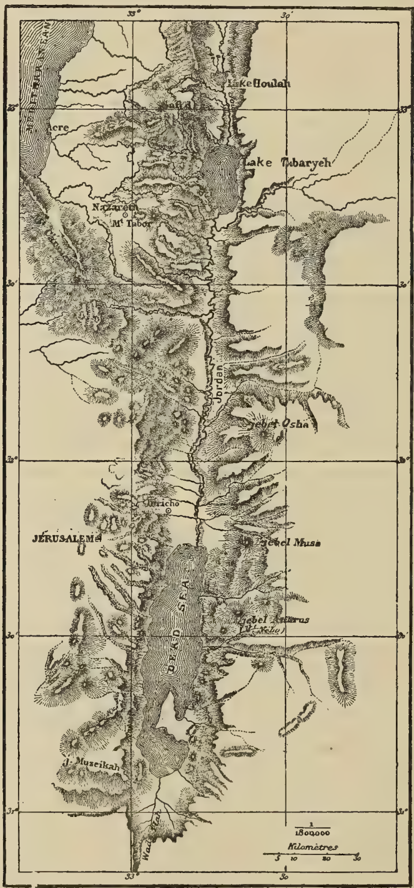
THE DEAD SEA.—THE SALT LAKES OF ASIA MINOR AND THE RUSSIAN STEPPES.—THE GREAT SALT LAKE.—THE MELR'IR.

ALTHOUGH the Caspian is the largest of all the inland seas, the Asphaltite Lake is in some respects the most curious on account of its position in a deep fissure of the earth, many hundreds of feet below the level of the Mediterranean. Since Schubert discovered, at the beginning of the century, this single instance of a similar depression, it has been ascertained by exact measurements that over an area of nearly 186 miles the whole valley ascending towards the base of Lebanon and lying parallel to the sea-shore of Palestine is lower than the ocean. Below the small Lake Huleh the River Jordan, which traverses the valley, flows into a cavity which deepens by quickly recurring steps below the ideal sea-line. The level of Lake Asphaltites, in which the waters of the river are lost, is 1,286 feet lower than that of the sea. The greatest depth reached by the sounding-line exceeds 984 feet, and is, therefore, 2,270 feet below the level of the Mediterranean. Thus the depression into which the Jordan falls is deeper than the whole extent of the Adriatic and several other marine basins in communication with the ocean. Lake Asphaltites, however, does not merit the name of sea from its depth and its intense saltness only; it also possesses its principal current, flowing from north to south, and continuing the course of the Jordan, and its counter-currents flowing on both sides parallel to the shore. The surface of the Dead Sea exceeds 460 square miles; but, as is proved by the horizontal layers of gypseous marl and the beds of salt deposited in stages on the slopes of the surrounding mountains, the level of the lake was formerly much higher than it is at present; and probably the water filled all the elongated space comprehended between the foot of Lebanon and the entrance to Arabah at the north of the Red Sea. The drying up of the ancient sea of the Sahara, and the consequent diminution of rains and increase of evaporation, is, perhaps, the cause which gradually lowered, century after century, this ancient sea, called so appropriately to this day the "Dead Sea."

In fact, the landscape thoroughly presents an aspect of death. The rocks are bare; nearly every spot on the shores is sterile; the waters themselves nourish with difficulty but a few living beings of the lowest order; the fish, crustaceans, and insects brought down by the Jordan and the surrounding mountain-torrents immediately die; aquatic plants are unable to grow. Off the mouth of a rivulet, the Wady-Mojeb, small fish are carried as far as a point in the lake where the density of the water is 1·115, but beyond this spot they inevitably perish. The only animals that have been found in the mud at the bottom are some species of

foraminifera, classified by Ehrenberg, the micrographer. This almost complete absence of living organisms was formerly attributed to the enormous proportion of sea-salt which is found in the water of the Dead Sea. This proportion is, in fact, very considerable, for it is twice as great as that in the Mediterranean; but there is, on the border of the lake, a small pond, the water of which is not less salt than

Fig. 180.—The Dead Sea and the Jordan.

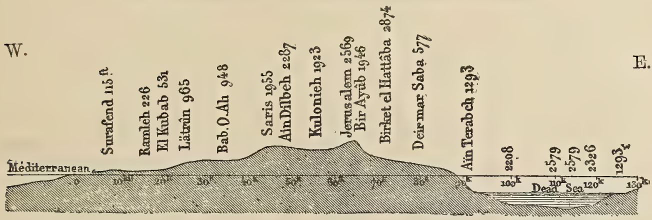


that of the Dead Sea, and yet a large quantity of small fish live in it, which are immediately killed by an immersion for a few moments in Lake Asphaltites. It is, then, probably chloride of magnesium and bromine which render the waters of this inland sea so completely destructive to animal life.

Chemical analyses have shown that the matters contained in the Dead Sea

differ greatly from those of sea-water, not only in proportion but also in number. Thus, chloride of magnesium is found in this lake in much greater abundance than sea-salt itself; the proportion of bromine is also most extraordinary, as it varies from less than 15 to more than 67 thousandth parts of the water. On the other hand, iodine, a substance the presence of which is so characteristic of the waters of the ocean, appears to be completely wanting in the water of the Dead Sea; neither are phosphorus, silver, cæsium, rubinium, nor lithium found in its water. It must be concluded that the Lake Asphaltites has never, since its formation, constituted a part of the sea, and that it is not, as was long supposed, an ancient prolongation of the Red Sea, separated from the rest of this gulf by the upheaving of the Arabah depression. Ehrenberg, however, had already come to this conclusion by ascertaining that not one of the foraminifera found in the mud of the Dead Sea belongs to any species discovered in the Red Sea. M. Lortet thinks that the chemical substances contained in the water of Lake Asphaltites proceed from thermal springs bubbling up on the shores, and especially from the bed of the lake. One fact which tends to confirm this hypothesis is, that the quantity of bromine increases with the depth of the water, the largest proportion of this substance being found at 984 feet from the surface. The fragments of bitumen which float on the surface of the water, and which have gained for the basin the name of Lake Asphaltites,

Fig. 181.—Section of Palestine from East to West.



also proceed from the springs in its bed. As regards the saltness properly so called, it must have naturally increased by the gradual concentration of the water. When the latter extended over a larger surface of the country, the proportion of sea-salt dissolved in the liquid mass must have been much less. When the sea retires, it of course leaves a saline sediment; but this sediment is conveyed into it partly by streams and by the Jordan itself, which empties into the lake about 90 cubic yards of water a second (?), containing 6½ bushels of sea-salt. At the present time the water of the Dead Sea, the specific gravity of which is in some places from 1·230 to 1·250, has almost reached the point of saturation; it deposits saline crystals at the bottom, and only dissolves to a very trifling extent the base of a cliff of rock-salt which overlooks the western coast.

All the great lakes of Asia Minor, situated at different altitudes between the two great depressions of the Dead Sea and the Caspian, are likewise rich in chemical substances. Lake Van, which covers an area of 1,544 square miles, especially contains sulphate of soda, which, during the dry season, when the waters are low, kills all the fish brought into it by the tributary streams. Lake Urmia, still more extensive than Lake Van, is chiefly remarkable for the enormous quantity of sea-salt which it holds in a state of solution; in this respect, it is only

equalled by the lagunes of the desert and steppes, where the salt is so concentrated that it is deposited upon the bottom in thick beds. Of this kind is Lake Elton, to the north-west of the Caspian. The bed of this sheet of water consists of immense layers of salt, to which each day adds a fresh sediment. In winter, the rivulets which empty themselves into this small closed basin bring a certain quantity of brine, which afterwards evaporates during the heat, leaving upon the soil a bed of crystals several inches in thickness. In summer, when the shores are not covered with water, they appear to extend as far as one can see, like an immense field of snow. Every year more than 220,550,000 lbs. of salt are extracted from Lake Elton, and yet the saltness of its waters has not perceptibly diminished.

The Great Salt Lake of America is another Dead Sea, into which falls another Jordan, and, by a strange historical coincidence, the Mormons have established themselves upon the shores of this very lake; for this sect call themselves the successors of the Jews, and the chosen people of the New World. This inland sea, the real shape of which has only been known since 1850, by means of the explorations of Stansbury is one of the most remarkable lacustrine sheets in the world; it is not less than 248 miles in circumference, but its depth is inconsiderable, nowhere exceeding 32 feet; the average is only about 6 feet.

The degree of saltness of the Great Lake varies according to the seasons and the durations of rain and drought; but it is always much more intense than that of the ocean. In fine weather, one might go to sleep on the waves of the lake without fear of being drowned; nevertheless, it is very difficult to swim in it on account of the effort which must necessarily be made in order to keep the legs below the surface. A single drop falling into the eye causes the most cruel suffering, and the water when swallowed produces paroxysms of spasmodic coughing. Stansbury doubts if the most experienced swimmer could escape death if he were exposed far from the shore to the violence of the waves and wind. Although the Great Lake only contains a very small proportion of those salts so destructive to animal life which are found in the Dead Sea, yet neither fish nor molluscs exist in it; life is represented only by sea-weed of the *Nostoc* tribe, and by a small worm which here and there burrows in the sand of the shores. The trout which are carried into its waters by the Jordan perish immediately. Nevertheless, the surface of the lake affords hospitality to innumerable flocks of gulls, wild geese, swans, and ducks. Whole armies of young pelicans, tended by their old lame guardian-birds, contemplate the waves from the top of all the ledges of rock, whilst the parents go to fish in the Bear, Weber, and Jordan rivers, all of which abound in fish. Not a tree grows upon the shores of the lake nor in the adjacent plains; the only vegetation to be seen far and wide is tufts of *Artemisia,* and other plants which delight in a soil impregnated with saline substances.

Formerly the Great Salt Lake, like all other inland seas saturated with salt, spread over a much more considerable area. The parallel basins of the plateau of Utah, and the lateral valleys which run into them, were the gulfs, bays, and straits of the inland sea. At a great height above the present level of the lake, the former alluvial shores and cliffs surround the valleys with their concentric rings traced upon the sides of the mountains. Even in the plains some distance off, the surface of which exhibits a thin bed of vegetable earth, the sub-stratum is lake-clay saturated with sea-salt and the sulphates of lime and magnesia. Agriculture, therefore, is nearly impossible upon these ancient lacustrine beds. In the earliest years of colonisation the damp and virgin earth still produced crops to some extent, but subsequently the vegetable soil has lost its nutritive elements, and the clayey

substratum coming in contact with the roots of the plants withers them up by means of its acrid properties.

Similar causes to those which led to the contraction of the Caspian and the Dead Sea have constantly tended to diminish the waters of Lake Utah, and also to saturate them with an enormous quantity of salt. The Great Basin is separated from the Pacific by high mountains of comparatively recent formation, which arrest the progress of the clouds, and prevent them from pouring upon the plateau the moisture derived from the sea. On the other hand, the evaporation is very considerable upon these high, rocky, and bare plains, and the winds which traverse them are but little impeded from carrying the vapours outside the basin of Utah. In consequence of this constant loss, the level of the Great Lake is become lower, the streams are dried up, the springs are exhausted, and the salt has concentrated more and more in the water. It is probable that, at the present time, an equilibrium is at length established between the annual fall of snow and rain and the

Fig. 182.—Lakes of Huiduck.

mists which rise from the surface of the diminished lake. Since the establishment of the Mormons in the territory of Utah, the level of the lake has alternately risen and sunk.

The various phenomena which take place in the waters of the Great Salt Lake, as well as in those of the Caspian, Lake Urmia, and the Dead Sea, are also produced in a multitude of other lacustrine basins of less importance, with all the variations caused by the difference of climate, the nature of the soil, and the composition of the water. But as a great number of these lakes are situated in regions destitute of rain, and owe their saltness to the copious evaporation which has abstracted so large a part of their waters, they are, in consequence of this diminution, of very small area and have become converted into lagoons and marshes. Sometimes, indeed, they are reduced to surfaces which are alternately muddy and white with salt, when they have been either wetted by some casual rains or dried up by the solar rays. As a type of these salt-tracts may be mentioned the steppes of Huiduck in the Ponto-Caspian isthmus, and the Shott Melr'ir, a range of marshes which stretch from east to west, over a length of more than 186 miles to the south of Jebel Aouress, formerly communicating with the Gulf of Great Syrtes, by the Strait of Cabes, at present choked up by sand. These marshes are separated one from another by isthmuses and islets of dry ground, and extend at unequal levels to 95, 118, 128, 213, 249, and even 279 feet below the sea. During the rainy season they are sheets of shallow water, which spread far and wide into the plains; during the dry season they are fields of salt, over which the mirage throws its illusions.

CHAPTER LX.

MARSHES.—SWAMPS OF NORTH AMERICA.—PEAT-BOGS.—UNHEALTHINESS OF MARSHES.

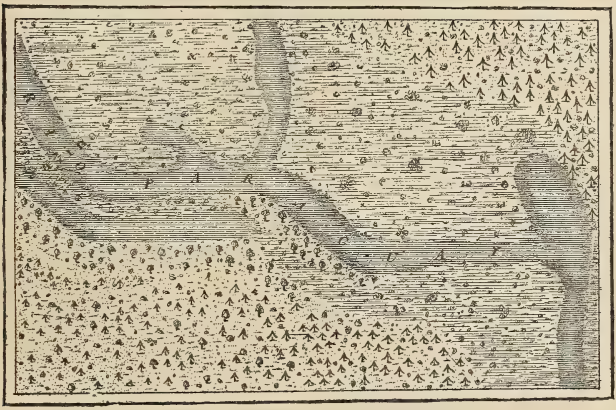
MARSHES proper are shallow lakes, the waters of which are either stagnant or actuated by a very feeble current; they are, at least in the temperate zone, filled with rushes, reeds, and sedge, and are often bordered by trees, which love to plunge their roots into the muddy soil. In the tropical zone a large number of marshes are completely hidden by multitudes of plants or forests of trees, between the crowded trunks of which the black and stagnant water can only here and there be seen. Marshes of this kind are inaccessible to travellers, except where some deep channel, winding in the midst of the chaos of verdure, allows boats to attempt a passage between the water-lilies, or under some avenue of great trees with their long garlands of creepers waving in the shade. Whatever may be the climate, it would, however, be impossible to draw any distinction, even the most vague, between lakes and marshes, as the level of these sheets of water oscillates according to the seasons and years, and as the greater number of lakes, principally those of the plains, terminate in shallow bays which are perfect marshes. Some very important lacustrine basins, among others Lake Tsad, one of the most considerable in all Africa, are entirely surrounded by swamps and inundated ground, which prohibit access to the lake itself, and prevent its true dimensions from being known.

In like manner, a portion of the course of many rivers traverses low regions in which marshes are formed, either temporary or permanent, the uncertain limits of which change incessantly with the level of the current. The borders of great watercourses, when left in their natural state, are the localities in which these marshy reservoirs principally exist, which, in the absence of basins and artificial weirs, are of very great importance to the regulation of the fluviatile discharge. The most remarkable marshes of this kind are perhaps those crossed by the Paraguay and several of its tributaries; they consist of wet prairies and interminable sheets of water which stretch away like a sea from one horizon to the other. They have received the names of Lakes Xarayes, Pantanal, &c. Farther south, certain tributaries of the Parana, the Maloya, the Batel, and the Sarandi, which cross the State of Corrientes from north-east to south-west, are nothing but wide marshes, the water of which overflows slowly across the grass on the imperceptible slope of the territory. There is indeed one of these marshes, the Laguna Bera, which drains simultaneously into the two great rivers of Parana and Uruguay.

These permanent inundations, however, cannot fail to disappear, sooner or later, before the encroachments of cultivation.

In the same way as the low river-shores are frequently converted into marshes, vast extents of the sea-coasts when but slightly inclined are also covered over by marshes, which are generally separated from the main sea by tongues of sand gradually thrown up by the waves. In these marshes, most of which once formed a part of the sea, and still mark its ancient outline, the water presents the most varied proportions of saline admixture. In some places, when evaporation is very active, the liquid is much more salt than the sea itself; but in other spots the marsh, fed by fresh water which comes from the interior, is scarcely brackish. The saltness of the water, however, constantly changes in all parts of the marsh, according to the alternations of flow and ebb and of rainy and dry weather. These half dried-up bays are rarely deep enough to allow of large vessels sailing in them,

Fig. 183.—Salt Marshes of Paraguay.

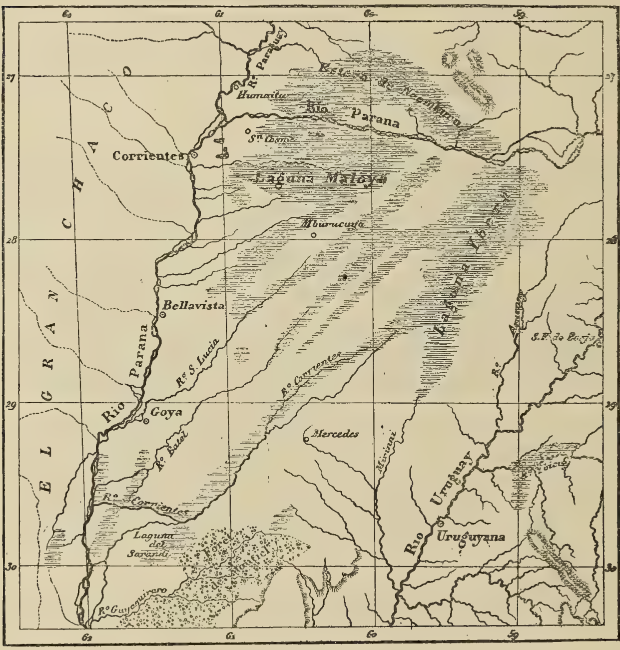


and their banks are generally overrun by the most luxuriant vegetation. The shore constantly keeps gaining upon them, and thus tends to the increase of the mainland.

The coasts which surround the Caribbean Sea and the Gulf of Mexico, and also the Atlantic shores of North America, from the point of Florida to the mouth of the Chesapeake, are bordered by a very large number of marine marshes, forming a continued series over hundreds and thousands of miles in length. In this immense series of coast-marshes all kinds of vegetation seem to flourish, and threaten to get the better of the mud and water, and to convert them into *terra firma*. To the south, upon the shores of Columbia and Central America, the mangroves and other trees of like species plunge the terminal points of their aerial roots deep into the mud, crossing and recrossing in an arch-like form, and retaining all the *débris* of plants and animals under the inextricable network of their natural scaffoldings. The shores of the Gulf of Mexico, in Louisiana, Georgia, and Florida, are bordered by cypress swamps, or forests of cypress (*Cupressus disticha*). These strange trees, the roots of which are entirely buried, throw out above the layer of water which covers

the soil multitudes of little cones, the business of which is to absorb the air. For millions of acres nearly all the marshy belt along the sea-shore is nothing but an immense cypress swamp, with trees bare of leaves, and fluttering in the wind their long hair-like fibres of moss. Here and there the trees and muddy soil give place to bays, lakes, or quaking meadows, formed by a carpet of grass lying upon a soil of wet mud, or even upon the hidden water. In Brazil, these buoyant beds of vegetation are frequently met with, and the significant name *tremendal* has been

Fig. 184.—Marshes of Corrientes.



given to them: in Ireland these are called "quaking-bogs." The least movement of the traveller who ventures upon them makes the soil tremble to some yards' distance.

To the north of Florida, in the Carolinas and Virginia, the belt of cypress swamps continues; but in consequence of the change of climate and vegetation, the quaking-meadows are gradually converted into peat-mosses. Evaporation being much less active in these countries than in those situated farther to the south, and the dry season being much less prolonged, the water arising from rain and inundation remains—as if in the pores of an immense sponge—in all the interstices of the entangled mass of mosses, *Sphagnum*, *Confervæ*, and other aquatic plants. The whole marsh swells towards the centre, because the aqueous particles, divided by innumerable stalks, cannot spread out laterally, and are drawn by capillary attraction into the fresh beds of plants formed above the older ones. The surface

of the marsh is incessantly renewed by a carpet of green vegetation; while below, the dead plants, deprived of air, carbonize slowly in the moisture which surrounds them. These are the beds of peat which form upon the ground just as the layers of coal were formed in previous geological epochs.

On the southern side, the first great peat-bog of a well-defined character is the "Dismal Swamp," which extends along the frontiers of North Carolina and Virginia. This spongy mass of vegetation rises 10 feet above the surrounding land. In the centre, and, so to speak, upon the summit of the marsh, lies Lake Drummond, the clear water of which is coloured reddish-brown by the tannin of plants. A canal, which crosses the Dismal Swamp to connect it with the adjacent streams, is obliged to make its way along the marsh by means of locks. To the north of Virginia peat-bogs proper become more and more numerous; and in Canada, Labrador, &c., they cover vast expanses of country. All the interior of the island of Newfoundland, inside of the enclosure formed by the forests on the shore, is nothing but a labyrinth—a great part of which is still unknown—of lakes and peat-bogs; even on the sides of the hills there are marshes on so steep an incline that the water from them would disappear and run off in a stream if it was not stopped by the thick carpet of plants which it saturates. Many a large peat-bog which may be crossed dry-shod contains more water than many lakes, filling a hollow of the valley with deep water.

Opposite Newfoundland, on the other side of the Atlantic, Ireland is hardly less remarkable for the enormous development of its peat-mosses or bogs. These tracts of saturated vegetation, in which *Sphagnum palustre* predominates, comprehend nearly two and a half millions of acres—the seventh part of the whole island. The inhabitants continue to extract from them, every year, immense quantities of fuel. The spaces left by the spade in the vegetable mass are gradually filled up again by new layers. After a certain number of years, which vary according to the abundance of rain, the depth of the bed of water, the force of vegetation, and the slope of the soil, the turf "quarry" is formed anew. In Ireland it generally takes about ten years to entirely fill up again the trenches, measuring from nine to thirteen feet in depth, which are made in the bogs on the plains, when a fresh digging of turf may be commenced. In Holland, crops of this fuel may be gathered on an average every thirty years. In other peat-moss districts the period of regeneration lasts forty, fifty, and even a hundred years. In France, on the borders of the Seugne (Charente-Inférieure), it has been ascertained that ditches 5 feet deep and nearly 7 feet wide are completely obstructed by vegetation after the lapse of twenty years. As for the beds of peat which carpet the sides of mountains, they take centuries to form afresh.

As everything in nature is continually changing and modifying, peaty marshes, like lakes, are all either in a period of increase or a period of decay—some form while others disappear. Independently of the action exercised by the labour of man, the vegetation of peat-bogs may cease to be produced in any basin, either because the water flows away naturally through some wide outlet after the heavy rains, or because some river, by changing its course, has exhausted or immoderately swollen the mass of water necessary to the nourishment of the peat; or, again, because the rain, becoming either more rare or more frequent, has dried up the basin or converted it into an inundated marsh; lastly, the sinking or upheaving of the soil may also, according to the various conditions of the relief of the country, be the cause of the disappearance of the flora of the peat-bogs. The same causes, acting in contrary directions, give rise to and increase these enormous masses of

plants swollen with water. In Ireland, the Low Countries, the north of Germany and Russia, heaps of trunks of former forest-trees—oaks, beech, alder, and other trees—are frequently discovered, which by their decay have made way for the peat-mosses. The *Sphagnum*, too, often takes possession of ground of which man had previously made himself master, and in many places roads, remains of buildings, and other vestiges of human labour are found below the modern bed of vegetation by which they are now covered. Certain peat-bogs in Denmark and Sweden may be considered, on account of the curiosities which have been found in them, as perfect natural museums, in which the relics of the civilisation of ancient nations have been preserved for the *savants* of our own day.

The air above the peat-mosses of Ireland and other countries in the world is not often unhealthy, either because the heat is not sufficient to develop miasma, or else because the vegetation, by absorbing the water into its spongy mass, impedes the corruption of the liquid, and produces a considerable quantity of oxygen. Farther south, the peat-mosses, which are intermixed with pools of stagnant water, and especially marshes properly so-called, generate an impure air, which spreads fever and death over the surrounding country. Unless marshes are surrounded with dense forests, which arrest the dispersion of the gases, the latter exercise a most injurious influence on the general salubrity of the district; for during dry weather, a vast area of the bed of the marshes becomes exposed, and the heaps of organic *débris* lying on the bottom decompose in the heat and infect the whole atmosphere. The average of life is much shorter in all marshy countries than in the adjacent regions which are invigorated by running water. In Brescia, Poland, in the marshes of Tuscany, and in the Roman plains, the wan and livid complexion of the inhabitants, their hollow eyes and feverish skin, announce at first sight the vicinity of some centre of infection. There are some marshes in the torrid zone where the decomposition of organic remains goes on with a much greater rapidity than in temperate climates; no one can venture on the edges of these districts without peril to his life. As Frœbel ascertained in his journey across Central America, the miasma is occasionally produced in such abundance that not only can it be smelt, but a distinct impression of it is left upon the palate. One of the most important works of civilisation is to deal with these unwholesome regions, which are still, as it were, undecided between land and water, and to render them fit for cultivation and to be the abode of man.

Part IV.

SUBTERRANEAN FORCES.

CHAPTER LXI.

ERUPTION OF ETNA IN THE YEAR 1865.—MUTUAL DEPENDENCE OF ALL TERRESTRIAL PHENOMENA.

THE Greek mythology, harmonising in this respect with the ideas of most nations which were acquainted with volcanoes, attributed to these mountains an origin altogether independent of the forces which are in action on the surface of the ground. According to the views of the Hellenes, water and fire were two distinct elements, and each had its separate domain, its genii, and its gods. Neptune reigned over the sea; it was he that unchained the storms and caused the waves to swell. The tritons followed in his train; the nymphs, sirens, and marine monsters obeyed his orders; and in the mountain valleys, the solitary naïds poured out to his honour the murmuring water from their urns. In the dark depth of unknown abysses was enthroned the gloomy Pluto; at his side Vulcan, surrounded by Cyclops, forged thunderbolts at his resounding anvil, and from their furnaces escaped all the flames and molten matter the appearance of which so appalled mankind. Between the gods of water and of fire there was nothing in common, except that both were the sons of Chronos, that is, of time, which modifies everything, which destroys and renews, and, by its incessant work of destruction, makes ready a place for the innumerable germs of vitality which crowd on the threshold of life.

Even in our days, the common opinion is not much at variance with these mythological ideas, and volcanic phenomena are looked upon as events of a character altogether different from other facts of terrestrial vitality. The latter, the sudden changes of which are visible and easily to be observed, are justly considered to be owing principally to the position of the earth in respect to the sun and the alternations of light and darkness, heat and cold, dryness and moisture, which necessarily result. As regards volcanoes, on the contrary, an order of entirely distinct facts is imagined, caused by the gradual cooling of the planet or the unequal tides of an ocean of lava and fire. Certainly, the eruptions of ashes and incandescent matter have not revealed the mystery of their formation, and in

this respect numerous problems still remain unsolved by scientific men. Nevertheless, the facts already known warrant us in asserting that volcanic crises are connected, like all other planetary phenomena, with the general causes which determine the continual changes of continents and seas, the erosion of mountains, the courses of rivers, winds, and storms, the movements of the ocean, and all the innumerable modifications which are taking place on the globe If, some day, we are to succeed in pointing out exactly and plainly how volcanoes likewise obey, either partially or completely, the system of laws which govern the exterior of the globe, the first and most important requisite is to observe with the greatest care all the incidents of volcanic origin. When all the premonitory signs and all the products of eruptions shall have been perfectly ascertained and duly classified, then the glance of science will be on the point of penetrating into, and duly reading, the secrets of the subterranean abysses where these marvellous convulsions are being prepared.

The last great eruption of Etna, that central pyramid of the Mediterranean, which the ancients named the "umbilicus of the world," is one of the most

Fig. 185.—"Coulee" of Monte-Frumento.

magnificent examples which can be brought forward of volcanic phenomena; and as it has, moreover, been studied most precisely and completely, it well deserves to be described in some detail.

The explosion had been heralded for some long time by precursory signs. In the month of July, 1863, after a series of convulsive movements of the soil, the loftiest cone of the volcano opened on the side which faces the south. The incandescent matter descended slowly over the plateau on which stands the "Maison des Anglais," and this building itself was demolished by the lumps of lava which were hurled from the mouth of the crater. In some places heaps of ashes several yards thick covered the slopes of the volcano. After this first explosion, the mountain never became completely calm; numerous fissures, which opened on the outer slopes of the crater, continued to smoke, and the hot vapour never ceased to jet out from the summit in thick eddies. Often, indeed, during the night, the reflection of the lava boiling up in the central cavity lighted up the atmosphere with a fiery red. The liquid, being unable to rise to the mouth of the crater, pressed against the external walls of the volcano, and sought to find an issue

through the weakest point of the crust by melting gradually the rocks that opposed its passage. Finally, in the night of the 30—31 of January, 1865, the wall of the crater yielded to the pressure of the lava; some subterranean roaring was heard; slight agitations affected the whole of the eastern part of Sicily, and the ground was rent open for the length of a mile and a half to the north of Monte-Frumento, one of the secondary cones which rise on the slope of Etna. Through this fissure, which opened on a gently-inclined plateau, the pent-up lava violently broke through to the surface.

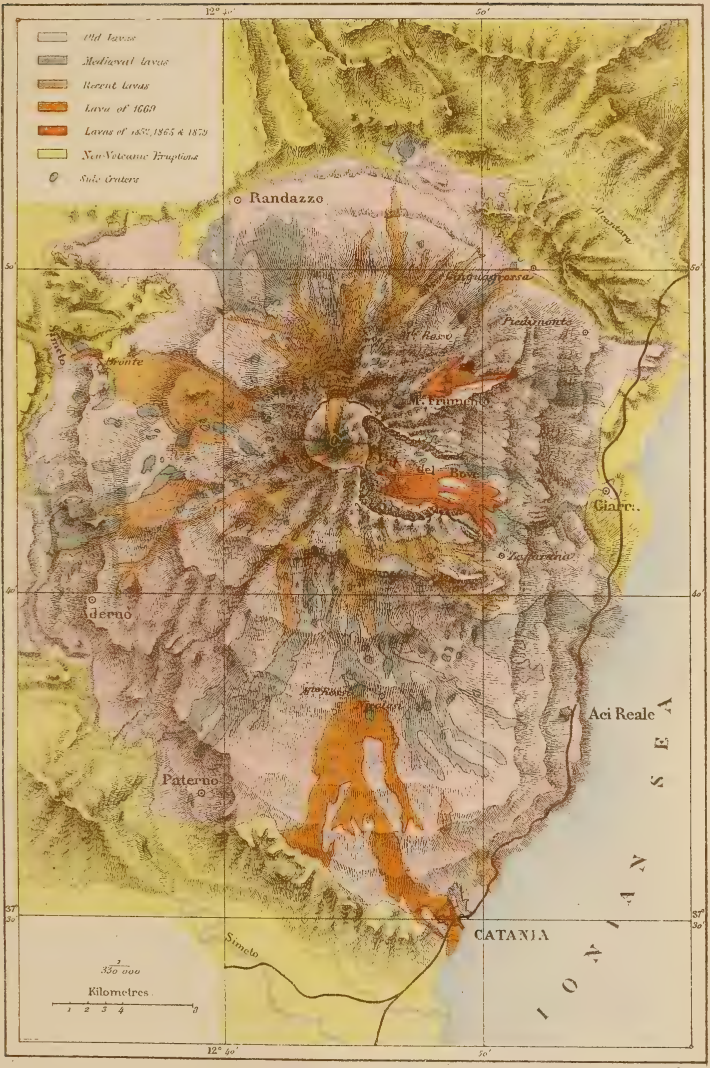
The fissure which opened on the side of the mountain, and could be easily followed by the eye to a point about two-thirds of the height of Monte-Frumento, in the direction of the terminal crater of Etna, seems to have vomited out lava but for a very few hours. Being soon obstructed by the snow and the *débris* of the adjacent slopes, it ceased to retain its communication with the interior of the mountain, and now resembled a kind of furrow, as if hollowed out by the rain-water on the side of the cone. On the 31st of January all the volcanic activity of the crevice was concentrated on the gently inclined plateau which extends at the base of Monte-Frumento, in the midst of which several new hillocks made their appearance. On the lower prolongation of the line of fracture, all the phenomena of the eruption properly so called were distributed in a perfectly regular way. Six principal cones of ejection were raised above the crevice, and gradually increased in size, owing to the *débris* which they threw out of their craters; these, gradually mingling their intervening slopes, and blending them one with another, absorbed in succession other smaller cones which had been formed by their sides, thus reaching a height of nearly 300 feet. Soon after the commencement of the eruption the two upper craters, standing close together on an isolated cone, vomited nothing but lumps of stone and ashes, while jets of still liquid lava were emitted by the lower craters, which were arranged in a semicircle round a sort of funnel-shaped cavity. In consequence of the specific gravities of the substances evacuated, a regular division of labour took place between the various points of the crevice. The projectiles which had solidified, the triturated *débris*, and the more or less porous fragments which floated on the top of the lava, made their escape by the higher orifices; but the liquid mass, being heavier and more compact, could only burst forth from the ground by the mouths opening at a less elevation.

Two months after the commencement of the eruption, the cone which was the nearest to Frumento ceased to send out either scoriæ or ashes. The funnel of the crater was filled up with *débris*, and the internal activity was revealed by vapours either of a sulphurous character or charged with hydrochloric acid. These rose like smoke from the slope of the hillock. The second cone, situated on a lower part of the fissure, remained in direct communication with the central flow of lava; but it was not in a constant state of eruption, and rested after each effort as if to take breath. A crash like that of thunder was the forerunner of the explosion; clouds of vapour, rolling in thick folds, gray with ashes, and furrowed with stones, darted out from the mouth of the volcano, darkening the atmosphere, and throwing their projectiles over a radius of several hundreds of yards round the hillock. Then, after having discharged their burdens of *débris*, the dark clouds, giving way before the pressure of the winds, mingled far and wide with the mists on the horizon. The lower cones, which rose immediately over the lava-source, continued to rumble and to discharge molten matter outside their cavities. The vapour which escaped from the seething well of lava crowded in dark contortions round the orifice of the craters. Some of it was red or yellow, owing to the reflection of the red-hot matter,

and some was variously shaded by the trains of *débris* ejected with it; but it was impossible to follow them with the eye, so rapid was their flight. An unintelligible tumult of harsh sounds simultaneously burst forth; they were like the noises of saws, whistles, and of hammers falling on an anvil. Sometimes one might have fancied it like the roaring of the waves breaking upon the rocks during a storm, if the sudden explosions had not added their thunder to all this uproar of the elements. One felt dismayed, as if before some living being, at the sight of these groups of hillocks, roaring and smoking, and increasing in size every hour, by the *débris* which they vomited forth from the interior of the earth. The volcano, however, then commenced to rest; the erupted matter did not rise much beyond 100 yards above the craters, whilst, according to the statement of M. Fouqué, at the commencement of the eruption it had been thrown to a height of 1,850 to 1,950 yards.

During the six first days the quantity of lava which issued from the fissure of Monte-Frumento was estimated at 117 cubic yards a second, equivalent to a volume twice the bulk of the Seine at low-water time. In the vicinity of the outlets the speed of the current was not less than 20 feet a minute; but lower down, the stream, spreading over a wider surface, and throwing out several branches into the side valleys, gradually lost its initial speed, and the fringes of scoriæ, which were pushed on before the incandescent matter, advanced on the average, according to the slope of the ground, not more than 1½ to 6 feet a minute. On the 2nd of February the principal current, the breadth of which varied from 300 to 550 yards, with an average thickness of 49 feet, reached the upper ledge of the escarpment of Colla-Vecchia, or Colla-Grande, three miles from the fissure of eruption, and plunged like a cataract into the gorge below. It was a magnificent spectacle, especially during the night, to see this sheet of molten matter, dazzling red like liquid iron, making its way in a thin layer from the heaps of brown scoriæ which had gradually accumulated up above; then, carrying with it the more solid lumps, which dashed one against the other with a metallic noise, it fell over into the ravine, only to rebound in stars of fire. But this splendid spectacle lasted only for a few days; the fiery fall, by losing in height, diminished gradually in beauty. In front of the cataract, and under the jet itself, there was formed an incessantly increasing slope of lava, which ultimately filled up the ravine, and, indeed, prolonged the slope of the valley above. From the reservoir, which was more than 160 feet deep, the stream continued to flow to the east towards Mascali, filling up to the brink the winding gorge of a dried-up rivulet.

By the middle of the month of February, the fiery stream, already more than six miles long, made but very slow progress, and the still liquid lava found it difficult to clear an outlet through the crust of stones cooled by their contact with the atmosphere; when, all of a sudden, a breaking out took place at the side of the stream, at a point some distance up, not far from the source. Then a fresh branch of the burning river, flowing towards the plains of Linguagrossa, swallowed up thousands of trees which had been felled by the woodman. This second inundation of lava did not, however, last long. The villages and towns situated at the base of the mountain were no longer directly menaced; but the disasters caused by the eruption were, notwithstanding, very considerable. A number of farmhouses were swept away; vast tracks of pasturage and cultivated ground were covered by slowly hardening rock, and—a misfortune which was all the worse on account of the almost general deforesting of Sicily—a wide band of forest, comprising, according to the various estimates that were made, from 100,000 to 130,000



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trees—oaks, pines, chestnuts, or birches, was completely destroyed. When seen from the lower part of the mountain, all these burning trunks borne along upon the lava, as if upon a river of fire, singularly contributed to the beauty of the spectacle. As is always the case in the events of this world, the misfortune of some proved to be a source of gratification to others. During the earliest period of the eruption, whilst the villagers of Etna looked at it with stupor, and were bitterly lamenting over the destruction of their forests, hundreds of curious spectators, brought daily by the steamboats from Catania and Messina, came to enjoy at their ease the contemplation of all the splendid horrors of the conflagration.

On the slopes of the Frumento, quite close to the upper part of the fissure, at a spot where the liquid mass had flowed like a torrent, M. Fouqué noticed a remarkable phenomenon: sheaths of solidified lava were surrounding the trunks of pines, and thus showing the height to which the current of molten stone had reached. In like manner the streams of obsidian which flow rapidly from the basin of Kilauea, in the Isle of Hawaii, leave behind them on the branches of the trees numerous stalactites, like the icicles which are formed by melting snow which has again frozen. Below the escarpments of the Frumento, the torrent, which was there retarded in its progress, had not contented itself with bathing for a moment the trunks of the forest-trees, but had laid them low. Great trunks of trees, broken down by the lava, lay stretched in disorder on the uneven bed of the stream, and although they were only separated from the molten matter by a crust a few inches thick, numbers of them were still clothed with their bark; several had even preserved their branches.

In some places rows of firs, very close together, were sufficient to change the direction of the flow, and to cause a lateral deviation. Not far from the crater of eruption, on the western bank of the great *cheire*, a trunk of a tree was noticed, which by itself had been able to keep back a branch of the stream, and to prevent it from filling up a glen which opened immediately below. This tree, being thrown down by the weight of the scoriæ, had fallen so as to bar up a slight depression in the ground which presented a natural bed to the molten matter. The latter had bent and cracked the trunk, but had failed in breaking it, and the stony torrent had remained suspended, so to speak, above the beautiful wooded slopes which it threatened to destroy completely.

And yet this last eruption, one of the most important in our epoch, is but an insignificant episode in the history of the mountain; it was but a mere pulsation of Etna. During the last twenty centuries alone, more than seventy-five eruptions have taken place, and in some of them the flows of lava have been more than twelve miles in length, and have covered areas of more than forty square miles, which were once in a perfect state of cultivation, and dotted over with towns and villages. In former ages thousands of other lava-flows and cones of ashes have gradually raised and lengthened the slopes of the mountain. The mass of Mount Etna, the total bulk of which is three or four thousand times greater than the most considerable of the rivers of stone vomited from its bosom, is, in fact, from its summit to its base, down even to the lowest submarine depths, nothing but the product of successive eruptions, throwing out the molten matter of the interior. The volcano itself has slowly raised the walls of its crater, and then extended its long slopes down to the waters of the Ionian Sea. By its fresh beds of lava and scoriæ incessantly renewed, it has ultimately reared its summit into the regions of snow, and has become, as Pindar called it, the great "pillar of heaven."

CHAPTER LXII.

SEA-COAST LINE OF VOLCANOES.—THE PACIFIC "CIRCLE OF FIRE."—VOLCANOES OF THE INDIAN OCEAN; OF THE ATLANTIC; OF THE MEDITERRANEAN; OF THE CASPIAN; OF CENTRAL ASIA.

THE earth being generally looked upon as immobility itself, it is a very strange thing to see it open to shoot out into the air torrents of gas, and shedding forth like a river the molten rocks of its interior. From what invisible source do all these fluid matters proceed which spread out in sheets over vast regions? Whence come those enormous bodies of steam, extensive enough to gather immediately in clouds round the loftiest summits, and sometimes indeed to fall in actual rain-showers? Science, as we have already said, has not completely answered these questions, the positive solution of which would be so highly important for our knowledge of the globe on which we live.

According to an ancient popular belief, Etna merely vomits forth, in the shape of vapour, the water which the sea has poured into the Gulf of Charybdis. This legend, although clothed in a poetic garb, has in fact become the hypothesis which is accepted by those *savants* who look upon volcanic eruptions as being a series of phenomena caused chiefly by water converted into steam.

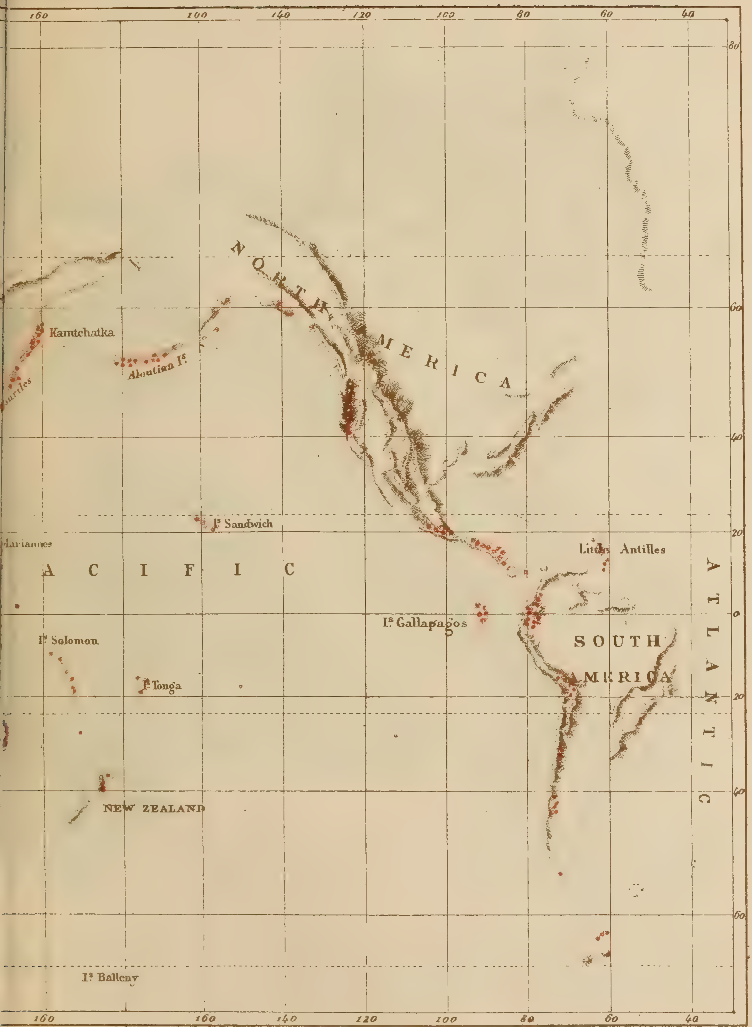
The remarkable fact that all volcanoes are arranged in a kind of line along the coasts of the sea, or of inland lacustrine basins, is one of the great points which testify in favour of this opinion as to the infiltration of water, and give to it a high degree of probability. The Pacific, which is the principal reservoir of the water of our earth, is circled round by a series of volcanic mountains, some ranged in chains, and others very distant from one another, but still maintaining an evident mutual connection, constituting a "circle of fire," the total development of which is about 22,000 miles in length. This ring of volcanoes does not exactly coincide with the semicircle formed by the coasts of Australia, the Sunda Islands, the Asiatic continent, and the western coasts of the New World. Like a crater described within some ancient and more extensive outlet of eruption, the great circle of igneous mountains extends its immense curve in a westward direction across the waves of the Pacific, from New Zealand to the peninsula of Alaska; on the east it is based on the coast of America, rising in the south so as to form some of the loftiest summits of the Andes.

The still smoking volcanoes of New Zealand—Tongariro, and the cone of Whakari, on White Island—are, in the midst of the southern waters of the Pacific properly so called, the first evidence of volcanic activity. On the north, a considerable space extends in which no volcanoes have yet been observed. The group

THE V


SPITZBERGEN
Jan Mayen
ICELAND
EUROPE
ASIA
Is Azores
Is Canaries
Mediterranean
AFRICA
ATLANTIC
Japan
Is Philippines
Mindanao
Sumatra
Borneo
Java
N. Guin
AUSTRALI
Fernando-Po
Ste Hélène
Tristan d'Acunha
I. St Paul
The Volcanos & Volcanic
regions are indicated
by red dots
The Mud Volcanos by blue dots

CANOS. PL.XX



Kamtchatka
Kuriles
Aleutian Is
NORTH AMERICA
Is Sandwich
Mariannes
PACIFIC
Little Antilles
ATLANTIC
Is Gallapagos
SOUTH AMERICA
Is Solomon
Is Tonga
NEW ZEALAND
Is Balleny

of the Fiji Islands, at which the volcanic ring recommences, presents a large number of former craters which still manifest the internal action of the lava by the abundance of thermal springs. At this point a branch crossing the South Sea in an oblique direction from the basaltic islands of Juan Fernandez as far as the active volcanoes of the Friendly group, unites itself with the principal chain which passes round, in a north-east direction, the coasts of Australia and New Guinea. The volcanoes of Abrim and Tanna in the New Hebrides, Tinahoro in the archipelago of Santa Cruz, and Semoya in the Solomon Isles, succeeding one after the other, connect the knot of the Fijis to the region of the Sunda Islands, where the earth is so often agitated by violent shocks. This region may be considered as the great focus of the lava-streams of our planet. On the kind of broken isthmus which connects Australia with the Indo-Chinese peninsula, and separates the Pacific Ocean from the great Indian seas, one hundred and nine volcanoes are constantly vomiting out lava, ashes, or mud, destroying from time to time the towns and the villages which lie upon their slopes; sometimes, in their more terrible explosions, they ultimately explode bodily, covering with the dust of their fragments areas of several thousands of miles in extent. From Papua to Sumatra,

Fig. 186.—Curve of Volcanic Islands.

every large island, including probably the almost unknown tracts of Borneo, is pierced with one or more volcanic outlets. There are Timor, Flores, Sumbawa, Lombok, Bali, and Java, which last has no less than forty-five volcanoes, twenty-eight of which are in a state of activity, and lastly, the beautiful island of Sumatra. Then, to the east of Borneo, Ceram, Amboyna, Gilolo, the volcano of Ternata—sung by Camöens—Celebes, Mindanao, Mindoro, and Fuzon: these form across the sea, as it were, two great tracks of fire.

Northward of Luzon, the volcanic ring curves gradually so as to follow a direction parallel to the coast of Asia. Formosa, the Liu-Kiu archipelago, and other groups of islands stand in a line over the submarine volcanic fissure; farther on, there are the numerous volcanoes of Japan, one of which, Fusiyama, with a cone of admirable regularity, is looked upon by the inhabitants of Niphon as a sacred mountain, from which the gods come down. The elongated archipelago of the Kuriles, comprising about a dozen volcanic orifices, unites Japan to the peninsula of Kamchatka, in which no less than fourteen volcanoes are reckoned as being in full activity. To the east of this peninsula, the range of craters suddenly changes its direction, and describes a graceful semicircle across the Pacific, from Behring

Island to the Point of Alaska. Thirty-four smoking cones stand on this great transversal dike, extending from continent to continent. Unimak, which rises on the extremity of the peninsula of Alaska, the peak of which is 7,939 feet in height, serves as the western limit of the New World, and is also pierced by a crater in a state of full activity.

Eastward of the peninsula, the volcanic chain extends along the sea-coast of the continent. Mount St. Elias, one of the highest summits in America, often vomits lava from its crater, which opens at an elevation of 17,716 feet. Farther to the south, another active volcano, Mount Fair Weather, rises to a height of 14,370 feet. Next comes Mount Edgecumbe, in Lazarus Island, and the volcanic region of British Columbia. The whole chain of the Cascades, in Oregon, as well as the parallel ranges of the Sierra Nevada and the Rocky Mountains, are overlooked by a great number of volcanoes; but only a few of them continue to throw out smoke and ashes: these are Mount Baker, Renier, and St. Helens, enormous peaks 10,000 to 16,000 feet high. In California and Northern Mexico, it is probable that the basaltic and trachytic mountains on the coast no longer present any outlets of eruption. Subterranean activity is not manifested with any degree of violence until we reach the high plateaux of Central Mexico. There a series of volcanoes, rising over a fissure crossing the continent, extends over the whole plateau of Anahuac, from the Southern Ocean to the Gulf of Mexico. The Colima, then the celebrated Jorullo, which made its appearance in 1759, the Nevado de Tolima, Istacihueti, Popocatepetl, Orizaba, and Tuxtla are the vents for the furnace of lava which is boiling beneath the Mexican plateau. To the south, in Guatemala and the South American republics, thirty burning mountains, much more active and terrible than those of Anahuac, rise in two chains, one of which is parallel to the sea-coast, and the other crosses obliquely the isthmus of Nicaragua. Among these numerous volcanoes there are some, the names of which have become famous on account of the frightful disasters which have been caused by their eruptions. Such are the mountains del Fuego and del Agua, above the Ciudad-Antigua of Guatemala; the Phare d'Isalco, which during the night lights up far and wide the plains of Salvador with its jets of molten stone and its column of red smoke; Coseguina, the last great eruption of which was probably the most formidable of modern times; the Viejo, Nuevo, Momotombo, and other mountains, which are almost worshipped from being so much dreaded.

The depressions of the Isthmuses of Panama and Darien interrupt the series of volcanoes which borders the coast of the Pacific. The peak of Tolima, which rises to the great height of 17,716 feet, is the most northern of the active volcanoes of South America, and is also one of the most distant from the sea among all the fire-vomiting mountains, for the distance from its base to the Pacific coast is not less than 124 miles. South of Tolima, and the great plateau of Pasto, where there likewise exists a crater, stands the magnificent group of sixteen volcanoes, some already extinct and some still smoking, over which towers the proud dome of Chimborazo. Occupying an elliptical space, the greater axis of which is only about 112 miles long, this group, comprising the Tunguragua, Carahuirazo, Cotopaxi, Antisana, Pichincha, Imbabura, and Sangay, is often looked upon as but one volcano with several cones of eruption; it is the cluster which, on the southern coasts of the Isthmus of Panama, corresponds symmetrically to the volcanic group of Anahuac. South of Sangay, which is perhaps the most destructive volcano on the earth, the chain of the Cordilleras offers no volcanoes for a length of about 930 miles; but in Southern Peru the volcanic series recommences, and outlets of

eruption still in action open at intervals amongst extinct volcanoes and domes of trachyte. The three smoking peaks of the inhabited part of Chili, the mountains of Antuco, Villarica, and Osorno terminate the series of the great American volcanoes; the activity of subterranean action is, however, disclosed by some other less elevated craters down to the extremity of the continent as far as the point of Tierra-del-Fuego. The South Shetland Islands, situated in the Southern Ocean, in a line with the New World, are likewise volcanic in their character; and if the same direction be followed towards the polar regions, the line will ultimately touch upon the coasts of the land of Victoria, on which rise the two lofty volcanoes of Erebus and Mount Terror, discovered by Sir John Ross. Stretching round the

Fig. 187.—Volcanoes of Ecuador.

sphere of the earth, the great volcanic circle is extended towards the north by various islets of the antarctic, and ultimately rejoins the archipelago of New Zealand. Thus is completed the great ring of fire which circles round the whole surface of the Pacific Ocean.

Within this immense amphitheatre of volcanoes a multitude of those charming isles, which are scattered in pleiads over the ocean, are also of volcanic origin, and many of them can be distinguished from afar by their smoking or flaming craters. Of this kind are some of the Marianne and Gallapagos Islands, which contain several orifices in full activity, and more than two thousand cones in a state of repose. Among these we must especially mention the Sandwich Islands, the lofty volcanoes of which rise in the middle of the central basin of the North Pacific like

so many cones of eruption in the midst of a former crater changed into a lake. The Mauna-Loa and Mauna-Kea, the two great volcanic summits of the island of Hawaii, are each more than 13,000 feet in height; and the eruptions of the first cone, which are still in full activity, must be reckoned among the most magnificent spectacles of this kind. On the sides of the Mauna-Loa opens the boiling crater of Kilauea, which is, without doubt, the most remarkable lava-source which exists on our planet.

Round the circumference of the Indian Ocean the border of volcanoes is much less distinct than round the Pacific; still it is possible to recognise some of its elements. To the north of Java and Sumatra, the volcanoes of which overlook the eastern portion of the basins of the Indian seas, stretches the volcanic archipelago of the Andaman and Nicobar Islands, in which there are several cones of eruption in full activity. On the west of Hindustan, the peninsula of Katch, and the delta of the Indus, are often agitated by subterranean forces. Many mountains on the Arabian coast are nothing but masses of lava; and, if various travellers are to be believed, the volcanic furnace of these countries is not yet extinct. Kenia, one of the two great mountains of Eastern Africa, has on its own summit a crater still in action—perhaps the only one which exists on this continent. Lastly, a large number of islands which surround the Indian Ocean on the west and on the south—Socotora, Mauritius, Reunion, St. Paul, and Amsterdam Island—are nothing but cones of eruption, which have gradually emerged from the bed of the ocean.

The volcanic districts which are scattered on the edge of the Atlantic are likewise distributed with a kind of symmetry round three sides of this great basin. On the north, Jan Mayen, so often wrapped in mist, and the more considerable island of Iceland, pierced by numerous craters, Hecla, the Skapta-Jokul, the Kotlugaja, and seventeen other mountains of eruption, separate the Atlantic from the Polar Ocean. At about 1,500 miles nearer the equator, the peaks of the Azores, some extinct and some still burning, rise out of the sea. The archipelago of the Canaries, over which towers the lofty mass of the peak of Teyda, continues towards the south the volcanic line of the Azores, and is itself prolonged by the smoking summits of the Cape Verde Islands. All the other mountains of lava which spring up from the bed of the Atlantic more to the south appear to have completely lost their activity, and on the coast itself there is, according to Burton, only one volcano still in action—that of the Cameroons. With regard to the "line of fire" along the Western Atlantic, it is developed at the entrance of the Caribbean Sea with perfect regularity, like the range of the Aleutian Isles. Trinidad, Grenada, St. Vincent, St. Lucia, Dominica, Guadeloupe, Montserrat, Nevis, St. Kitts, and St. Eustatius are so many outlets of volcanic force, either through their smoking craters or their mud-volcanoes, their *solfataras* or their thermal springs. North and south of the Antilles, the eastern coast of America does not present a single vent of eruption. It is a remarkable fact that the two volcanic groups of the Antilles and the Sunda Islands are situated exactly at the antipodes one of the other, and also in the vicinity of the two poles of flattening, the existence of which on the surface of the globe has been proved by the recent calculations of astronomers. More than this, these two great volcanic centres, which are undoubtedly the most active on the whole earth, flank, one on the west and the other on the east, the immense curve of volcanoes which spreads round the Pacific.

CHAPTER LXIII.

TORRENTS OF STEAM ESCAPING FROM CRATERS.—GASES PRODUCED BY THE DECOMPOSITION OF SEA-WATER.—HYPOTHESES AS TO THE ORIGIN OF ERUPTIONS.—INDEPENDENCE OF THE SEVERAL VOLCANIC OUTLETS.

ONE of the most decisive arguments which can be used in favour of a free communication existing between marine basins and volcanic centres, is drawn from the large quantities of steam which escape from craters during an eruption, and compose, according to M. Ch. Sainte-Claire Deville, at least 999 thousandths of the supposed volcanic smoke. During the eruption of Etna, in 1865, M. Fouqué attempted to gauge approximately the volume of water which made its escape in a gaseous form from the craters of eruption. By taking as his scale of comparison the cone which appeared to him to emit an average quantity of steam, he found this mass, reduced to a liquid state, would be equivalent to about 79 cubic yards of water for each general explosion. Now, as these explosions took place on the average every four minutes during a hundred days, he arrived at the result, that the discharge of water during the continuance of the phenomenon might be estimated at 2,829,600 cubic yards of water—a flow equal to that of a permanent stream discharging 55 gallons a second. Added to this, account ought to have been taken of the enormous convolutions of vapour which were constantly issuing from the great terminal crater of Etna, and, bending over under the pressure of the wind, spread out in an immense arch around the vault of the sky. In great volcanic eruptions it often happens that these clouds of steam, becoming suddenly condensed in the higher layers of the atmosphere, fall in heavy showers of rain, and form temporary torrents on the mountain-sides. According to the statements of Sir James Ross, the mountain Erebus, of the antarctic land, is covered with snow, which it has just vomited forth in the form of vapour. It has besides been remarked that the vapour which issues from volcanoes is not always warm; often, according to Pœppig, it is of the same temperature as the surrounding air.

As was said long since by Krug von Nidda, a German *savant*, volcanoes must be looked upon as enormous intermittent springs. The basaltic flows may be compared to streams on account of the water which they contain. It is probable that most of the lava which flows from volcanic fissures owes its mobility to the innumerable particles of vapour which fill up all the interstices of the moving mass. Being composed in great measure of crystals already formed, as may be proved by an examination of the *cheires*, in the body of which may be noticed nodules and crystals rounded by friction, the lava would be unable to descend over the slopes if it were not rendered fluid by its mixture with steam; and the gradual slackening

in speed and ultimate stoppage of the flow are chiefly caused by the setting free of the gases which served as a vehicle to the solid matter. Owing to this rapid loss of their humidity, basalts contain in their pores but a very slight quantity of water in comparison with other rocks. Yet even old lavas themselves contain as much as 10 to 19 thousandths of water at the edges of the bed, and 5 to 18 thousandths at the centre.

The various substances which are produced from craters also tend to show that sea-water has been decomposed in the great laboratory of lava. Ordinary salt, or chloride of sodium, which is the mineral that is most abundant in sea-water, is also that which is deposited the first and most plentifully round the orifices of eruption. Sometimes, the scoriæ and ashes are covered for a vast space with a white efflorescence, which is nothing but common salt; one might fancy it a shingly beach which had just been left by the ebbing tide. After each eruption of Hecla, the Icelanders are in the habit, it is said, of collecting salt on the slopes. The lava from the eruption of Frumento, analyzed by Fouqué, contained about 13 ten-thousandths of marine salt.

Almost all the other component parts of sea-water are likewise found in the gases and deposits of *fumerolles;* only the salts of magnesia have disappeared, but still are found under another form among the volcanic products. Being decomposed by the high temperature, just as they would be in the laboratory of a chemist, they go to constitute other bodies. Thus the chloride of magnesium is changed into hydrochloric acid and magnesia; the gas escapes in abundance from the *fumerolles,* whilst the magnesium remains fixed in the lava.

As Sainte-Claire Deville was the first to ascertain with certainty, four successive periods may be observed in every eruption, each of which assumes a distinct character owing to the exhalation of certain substances. After the first period, remarkable especially for marine salt and the various compounds of soda and potash, comes a second in which the temperature is lower, and during which brilliantly coloured deposits of chloride of iron are formed and hydrochloric and sulphurous acids are expelled. When the temperature is below 392° (Fahr.), there are ammoniacal salts and needles of sulphur, which are found in yellowish masses on the scoriæ of lava. Lastly, when the heat of the erupted bodies is below 212° (Fahr.), the *fumerolles* eject nothing but steam, nitrogen, carbonic acid, and combustible gases. Thus the activity of the exhalations and deposits is in proportion to the incandescence of the lava. At the commencement of the eruption, the orifices throw out a large quantity of substances, from marine salt to carbonic acid; but by degrees the power of elaboration weakens simultaneously with the heat, and the gases ejected gradually diminish in number, and testify, by their increasing rarity, to the approaching cessation of volcanic phenomena. In consequence of the difference which is presented by the exhalations during the various phases of eruptions of lava, observers have, at first sight, thought that each volcano was distinguished by emanations peculiar to itself. Hydrochloric acid was looked upon as one of the normal products of Vesuvius, and sulphurous vapours as more special to Etna. It was stated (with Boussingault) that carbonic acid was exhaled especially by the volcanoes of the Andes; and, with Bunsen, it was believed that combustible gases prevailed in the eruptions of Hecla.

In his beautiful investigations into the various chemical phenomena presented by Etna and the neighbouring volcanic outlets, such as Vesuvius and Stromboli, Fouqué appears to have established the now undoubted fact, that the gradual series of these emanations is just that which would be produced by the decomposition of

sea-water. Besides, in lava we also find iodine and fluorine, both of which we should expect to detect in it on account of their presence in sea-water. The salts of bromine, of which, however, only a slight trace is found in sea-water, have not yet been detected in volcanic products, which, no doubt, proceeds from the difficulty which chemists have experienced in separating such very small quantities.

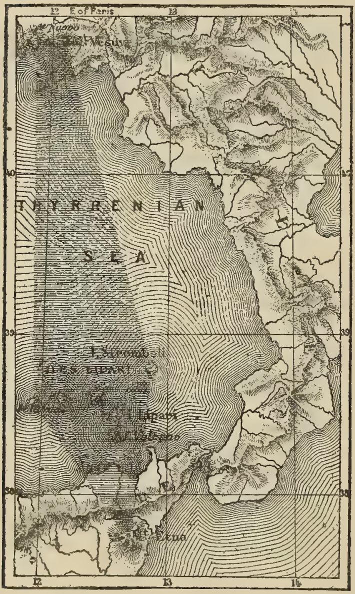
The other substances ejected by eruptions are of terrestrial origin, and evidently proceed from rocks reduced by heat to a liquid or pasty state; they consist principally of silica and alumina, and contain, besides lime, magnesia, potash, and soda. Oxides of iron also enter into the composition of lava, to the extent of more than one-tenth, which is a very considerable proportion, and warrants us in looking upon the volcanic flows as actual torrents of iron-ore; sometimes, indeed, this metal appears in a pure state. It is to this presence of iron that lava especially owes its reddish colour, and the sides of the crater their diversely coloured rocks. Compounds of copper, manganese, cobalt, and lead are also met with in lava; but, in comparison with the iron, they are but of slight importance. Lastly, phosphates, ammonia, and gases composed of hydrogen and carbon, are discharged during eruptions. The presence of these bodies is explained by the enormous proportion of animal and vegetable matter which is decomposed in sea-water. Ehrenberg found the remains of marine animalculæ in the substances thrown out by volcanoes.

When the water, either of seas or rivers, penetrates into the crevices of the terrestrial envelope, it gradually increases in temperature, like the rocks it passes through. It is well known that this increase of heat may be estimated on the average, at least as regards the external part of the planet, at 1° (Fahr.) for every 54 feet in depth. Following this law, water descending to a point 7,500 feet below the surface would show, in the southern latitudes of Europe, a temperature of about 212° (Fahr.). But it would not on this account be converted into steam, but would remain in a liquid state, owing to the enormous pressure which it has to undergo from the upper layers. According to calculations, which are based, it is true, on various hypothetical data, it would be at a point more than nine miles below the surface of the ground that the expansive force of the water would attain sufficient energy to balance the weight of the superincumbent liquid masses, and to be suddenly converted into steam at a temperature of 800° to 900° (Fahr.). These gaseous masses would then have force to lift a column of water of the weight of 1,500 atmospheres; if, however, from any cause, they cannot escape as quickly as they are formed, they exercise their pressure in every direction, and ultimately find their way from fissure to fissure until they reach the fused rocks which exist in the depths. To this incessantly increasing pressure we must, therefore, attribute the ascent of the lava into vent-holes of volcanoes, the occurrence of earthquakes, the fusion and the rupture of the terrestrial crust, and finally, the violent eruptions of the imprisoned fluids.

The direct observations which have been made on volcanic eruptions have now rendered it a very doubtful point whether the lavas of various volcanoes proceed from one and the same reservoir of molten matter, or from the supposed great central furnace which is said to fill the whole of the interior of the planet. Volcanoes which are very close to one another show no coincidence in the times of their eruptions, and vomit forth, at different epochs, lavas which are most dissimilar both in appearance and mineralogical composition. These facts would be eminently impossible if the craters were fed from the same source. Etna, the group of the Lipari Isles, and Vesuvius, have often been quoted as being

volcanic outlets placed upon the same fracture of the terrestrial crust; and it is added, in corroboration of this assertion, that a line traced from the Sicilian volcano to that of Naples passes through the ever-active furnace of the Lipari Isles. Although the mountain of Stromboli, so regular in its eruptions, is situated on a line slightly divergent from the principal line, and, on the other side, the volcanic isles of Salini, Alicudi, and Felicudi tend from east to west, it is possible and even probable that Vesuvius and Etna are in fact situated on fissures of the earth which were once in mutual communication. But during the thousands of years in which these great craters have been at work, no connection between their eruptions has ever been positively certified.

Fig. 188.—Line of Fracture between Etna and Vesuvius.



Sometimes, as in 1865, Vesuvius vomits forth lava at the same time as Etna; sometimes it is in a state of repose when its mighty neighbour is in full eruption, and rouses up when the lava of Etna has cooled. There is nothing which affords the slightest indication of any law of rhythm or periodicity in the eruptive phenomena of the two volcanoes. The inhabitants of Stromboli state that, during the winter of 1865, at the moment when the sides of Etna were rent, the volcanic impulse manifested itself very strongly in their island by stirring up the always agitated waves of the lava-crater which commands their vineyards and houses. A comparative calm, however, soon succeeded this temporary effervescence, and in the adjacent island of Volcano no increase of activity was noticed. If the shafts of Etna, Vesuvius, and the intervening volcanoes take their rise in one and the same ocean of liquid lava, all the lower craters must necessarily overflow simultaneously with the most elevated. Now, as has often been noticed, the lava may ascend to the summit of Etna, at a height of 10,827 feet, without a simultaneous flow of rivers of molten stone from Vesuvius, Stromboli, and Volcano, which are respectively but one-third, one-fourth, and one-tenth the height of the former. In like manner, Kilauea, situated on the sides of Mauna-Loa, in the Isle of Hawaii, in no way participates in the eruptions of the central crater opening at a point 9,800 feet higher up, and not more than 12 miles away. If there is any present geological connection between the volcanoes of one and the same region, it probably must be attributed to the fact of their phenomena depending on the same climatic causes, and not because their bases penetrate to one and the same ocean of fire. Volcanic orifices are not, therefore, "safety valves," for two centres of activity may exist on one mountain without their eruptions exhibiting the least appearance of connection.

CHAPTER LXIV.

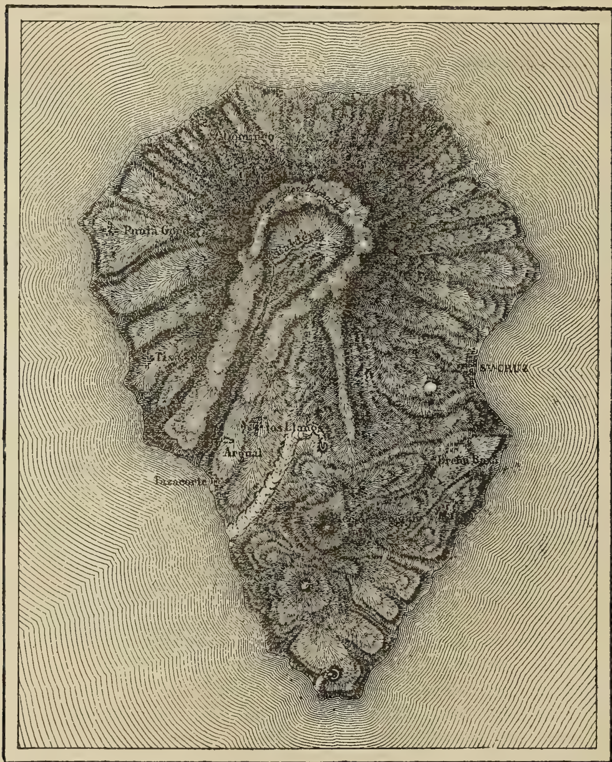
GROWTH OF VOLCANOES.—THEORIES OF HUMBOLDT AND LEOPOLD VON BUCH AS TO THE UPHEAVAL OF CRATERS.—DISAGREEMENT OF THESE THEORIES WITH THE FACTS OBSERVED.

CONSIDERED singly, each volcano is nothing but a mere orifice, temporary or permanent, through which a furnace of lava is brought into communication with the surface of the globe. The matter thrown out accumulates outside the opening, and gradually forms a cone of *débris* more or less regular in its shape, which ultimately attains to considerable dimensions. One flow of molten matter follows another, and thus is gradually formed the skeleton of the mountain; the ashes and stones thrown out by the crater accumulate in long slopes; the volcano simultaneously grows wider and higher. After a long succession of eruptions, it at last mounts up into the clouds, and then into the region of permanent snow. At the first outbreak of the volcano the orifice is on the surface of the ground; it is then prolonged like an immense chimney through the centre of the cone, and each new river of lava which flows from the summit increases the height of this conduit. Thus the highest outlet of Etna opens at an elevation of 10,892 feet above the level of the sea; Teneriffe rises to 12,139 feet; Mauna-Loa, in Hawaii, to 13,943 feet; and, more gigantic still, Sangay and Sahama, in the Cordilleras, attain to 18,372 and 23,950 feet in elevation.

This theory of the formation of volcanic mountains by the accumulation of lava and other matters cast out of the bosom of the earth presents itself quite naturally to one's mind. Most *savants*, from Saussure and Spallanzani down to Virlet, Constant Prévost, Poulett, Scrope, and Lyell, have been led by their investigations to adopt it entirely; indeed, in the present day it is scarcely disputed. It is true that Humboldt, Leopold von Buch, and, following them, M. Elie de Beaumont, have put forth quite a different hypothesis as to the origin of several volcanoes, such as Etna, Vesuvius, and the Peak of Teneriffe. According to their theory volcanic mountains do not owe their present conformation to the long-continued accumulation of lava and ashes, but rather to the sudden upheaval of the terrestrial strata. During some revolution of the globe, the pent-up matter in the interior suddenly upheaves a portion of the crust of the planet into the form of a cone, and opens a funnel-shaped gulf between the dislocated strata, thus by one single paroxysm producing lofty mountains, as we now see them. As an important instance of a crater thus formed by the upheaval and rupture of the terrestrial strata, Leopold von Buch mentions the enormous abyss of the Isle of Palma, known by the natives under the name of *Caldera*, or "Caldron." This funnel-shaped cavity is of enormous dimen-

sions, and is not less than four or five miles in width on the average; the bottom of it is situated about 2,000 feet above the level of the sea. Lofty slopes, from 1,000 to 2,000 feet in height, rise round the vast amphitheatre, and abut upon inaccessible cliffs, the upper ledges of which reach a total altitude of 5,900 to 6,900 feet in height. The highest point, the Pico-de-los-Muchachos, is covered with snow during the winter months; and although it penetrates into regions of the atmosphere which are of a very different character from those of the rest of the island, the slope that

Fig. 189.—Isle of Palma.



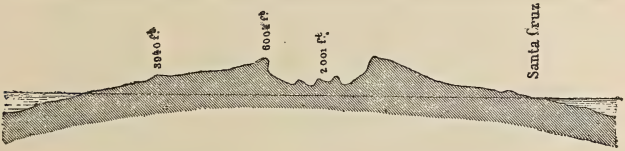
is turned towards the crater is so steep that blocks of stone falling from the summit roll down into the enclosed hollow.

Elie de Beaumont, as his chief support of Leopold von Buch's hypothesis, brought forward the fact that most of the strata of lava—a section of which may be seen on the sides of Etna, in the immense amphitheatre of the Val del Bove—are very sharply inclined. The celebrated geologist affirmed that thick sheets of molten matter could not run down steep slopes without being very soon reduced, in consequence of the acceleration of their speed, into thin layers of irregular

scoriæ. If this were really the case, the position of the thick flows of lava in the Val del Bove must have changed since the date of the eruption ; it would then be necessary to admit that they have been violently tilted up after having been originally deposited on the soil in sheets, which were either horizontal or very gently sloped. Nevertheless, the recent observations made by Sir C. Lyell, those of Darwin on the cones of the Gallapagos Isles, and of Dana on the lava flows of Kilauea, lastly, the remarks of the Italian *savants* who studied on the spot the volcanic phenomena of Vesuvius and Etna, have satisfactorily proved that in modern times a great number of rivers of lava, and especially that of the Val del Bove, in 1852 and 1853, have flowed over steep slopes varying in inclination from 15 to 40 degrees. It must, besides, be understood that the lava which poured over the steepest slopes was exactly that portion which, not having experienced any cause of delay, or met with any obstacle in its course, presented layers of the most uniform consistence and the most regular action.

One of the strongest arguments of scientific men in favour of the theory of upheaval is, that certain volcanic mountains, especially that of Monte-Nuovo, of Pouzzoles, and Jorullo, in Mexico, had been suddenly raised up by the swellings of the soil. Now, the unanimous testimony of those who, more than three centuries ago, witnessed the eruption of Monte-Nuovo is, that the earth was cleft open, affording an outlet to vapour, ashes, scoriæ, and lava, and that the hill, very

Fig. 190.—Section of the Island of Palma from South-east to North-West.

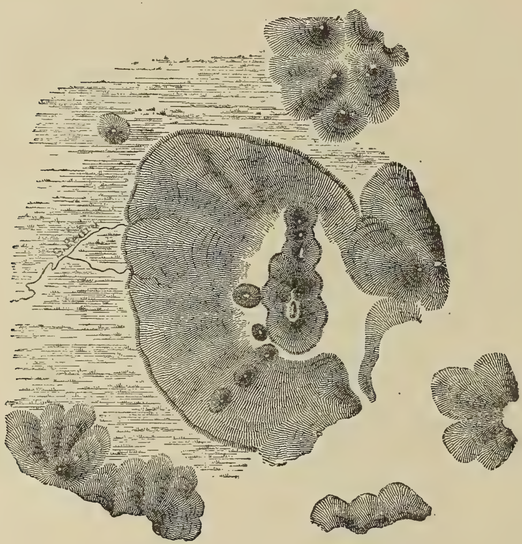


much lower than some of the subordinate cones of Etna, gradually rose during four days by the heaping up of the matter thrown out. The total volume of this eruption was no doubt considerable, but, compared with the amount of matter which flowed down upon Catania in 1669, or with the rivers of lava from Skaptar-Jokul, it is a mass of no great importance. Added to this, if the soil was really upheaved, how was it that the neighbouring houses were not thrown down, and that the colonnade of the Temple of Neptune, which stands at the foot of the mountain, kept its upright position ? With regard to Jorullo, which rises to a height of more than 1,650 feet, the only witnesses of this volcano making its first appearance were the Indians, who fled away to the neighbouring heights, distracted with terror. We have, therefore, no authentic testimony on which we can base an hypothesis as to any swelling up of the ground in the form of a blister. Quite the contrary; the travellers who have visited this Mexican volcano since Humboldt have discovered beds of lava lying one over the other, as in all other cones of eruption ; and more than this, they have also ascertained that none of the strata in the ground overlooked by the mountain have been at all tilted up.

Doubtless local swellings have often been observed in the burning matter issuing from the interior of the earth ; in many places the lava is pierced by deep caverns, and entire mountains—especially that of Volcano—have so many hollows in the rocks on their sides that every step of the climber resounds on them as if on a vault. Besides, the lava itself, being a kind of impure glass, is so pervaded by bubbles

filled with volatile matter that, when acted upon by fire, so as to expel the water and the gas, it loses on an average, according to Fouqué, two-thirds of its weight. But these caverns, these hollows and bubbles, proceed from the mixture of the lava with vapour which is liberated with difficulty from the viscous mass, or are caused by the longitudinal rupture of the strata during an eruption, and can in no way be compared to the immense blister-like elevation which would be formed by the strata

Fig. 191.—Volcano of Jorullo, Mexico.



of a whole district being tilted up to a height of hundreds, or even thousands, of yards, leaving at the summit, between two lines of fracture, room for an immense cavity.

None of these prodigious upheavals have been directly observed by geologists, and none of the legends invented by the fears of our ancestors, referring to the sudden appearance of volcanic mountains, have been since confirmed. Lastly, the very structure of the peaks which are said to have risen abruptly from the midst of the plains testifies to the gradual accumulation of material that has issued from the bowels of the earth. It is, therefore, prudent to dismiss definitively an hypothesis which marks an important period in the history of geology, but which, for the future, can only serve to retard the progress of science.

CHAPTER LXV.

NUMBER AND ARRANGEMENT OF VOLCANIC OUTLETS.—FORM OF VOLCANIC CONES AND CRATERS.

AS, when the burning matter seeks an outlet, the earth is generally cleft open in a straight line, the volcanic orifices are frequently distributed somewhat regularly along a fissure, and the heaps of erupted matter follow one another like the peaks in a mountain chain. In other places, however, the volcanic cones rise without any apparent order on ground that is variously cleft; just as if a wide surface had been softened in every direction, and had thus allowed the molten matter to make its escape, sometimes at one point, sometimes at another. From the

Fig. 192.—Series of Craters, Hawaii.

town of Naples—which is itself built on half a crater in great part obliterated—to the Isle of Nisida, which is an old volcano of regular form, the Phlegræan Fields present a remarkable example of this confusion of craters. Some are perfectly rounded, others are broken into, and their circle is invaded by the waters of the sea. Grouped for the most part in irregular clumps, even encroaching upon one

another and blending their walls, they give to the whole landscape a chaotic appearance. As Mr. Poulett Scrope very justly remarks, the aspect of the terrestrial surface at this spot reminds one exactly of the volcanic districts of the moon, dotted over, as it is, with craters.

As the type of a region pierced all over with volcanic orifices, we may also mention the Isthmus of Auckland in New Zealand, where Dr. Hochstetter has reckoned, in an area of 230 square miles, sixty-one independent volcanoes, 520 to 650 feet in height on the average. Some are mere cones of tufa; others are heaps of scoriæ, or even eruptive hillocks, which have shed out round them long flows of

Fig. 193.—Auckland and its Volcanoes.

lava. At one time the Maori chiefs used to intrench themselves in these craters as if in citadels; they escarped the outer slopes in terraces, and furnished them with palisades. At the present day, the English colonists, having become lords of the soil, have constructed their farms and country houses on these ancient volcanoes, and are constantly bringing the soil under cultivation.

The Safa, in the Jebel-Hauran, is also a complete chaos of hillocks and abysses. On this plateau of 460 square miles, which the Arabs call a "portion of hell," almost all the craters open on the surface of the ground, and not on the summits of volcanoes scattered here and there on the black surface. In every direction there may be seen rounded cavities like the vacuities formed in scoriæ by bubbles of gas,

only these cavities are 600 to 900 feet wide, and 65 to 160 feet deep. Some are isolated; some either touch or are separated by nothing but narrow walls like masses of red or darkish-coloured glass. One hardly cares to venture on these narrow isthmuses, bordered by precipices, and intersected here and there by fissures.

The normal form of the volcanoes in which the work of eruption takes place is

Fig. 194.—Cone of Tuff.

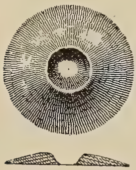
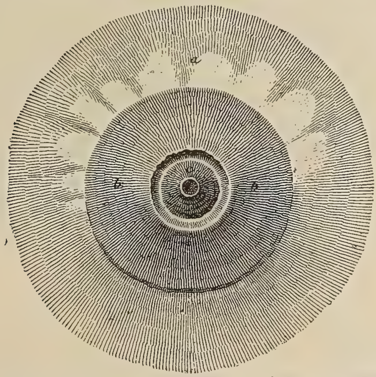


Fig. 195.—Cone of Tuff, and Crater of Scoriæ.

that of a slope of *débris* arranged in a circular form round the outlet. Whether the volcano be a mere cone of ashes or mud only a few yards high, or rise into the regions of the clouds, vomiting streams of lava over an extent of 10 or 20 miles, it none the less adheres to the regular form so long as the eruptive action is maintained in the same channel, and the *débris* thrown out falls equally on the external slopes.

Fig. 196.—Plan and Section of the Volcano of Rangitoto.



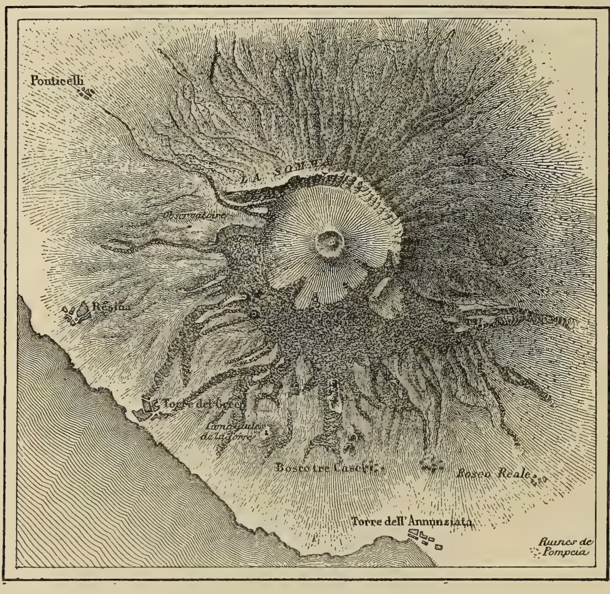
a. Declivities of Tuff. *b.* Cone of Lava. *c.* Pyramid of Scoriæ.

The beauty of the cone is increased by that of the crater. The terminal orifice from which the lava boils out well deserves, from the purity of its outline, its Greek name of "cup," and the harmony of its curve contrasts most gracefully with the declivity of the slope. In some volcanoes the symmetry of the architectural lines is so complete, that the crater itself contains a cone placed exactly in the

centre of the cavity, and pierced by a second crater in miniature, from which vapour makes its escape.

Volcanoes in which the eruptive action frequently changes its position—and these are the more numerous class—do not possess this elegance of outline. Very often the upheaved lava finds some weak place in the walls of the crater; it hollows them out at first, and then, bringing all its weight to bear on the rocks which oppose its passage, it ultimately completely breaks down the edge of the crater, leaving perhaps only one side standing. Among the European volcanoes, Vesuvius is the best example of these ruptured craters. Before A.D. 79, the escarpments of La Somma, which now surround with their semicircular rampart the terminal cone

Fig. 197.—Mount Vesuvius.



of Vesuvius, were the real crater. The portion of it which no longer exists disappeared and buried under its *débris* the towns of Herculaneum and Pompeii.

Active volcanoes, however, never cease to increase in all their dimensions, and sooner or later the breach is ultimately repaired; the remains of the former craters are gradually hidden under the growing slopes of the central cone. Thus, a former crater on Etna, which was situated at a point three miles in a straight line from the present outlet, at the commencement of the Val del Bove, has been gradually obliterated by the lava of successive eruptions: prolonged explorations on the part of MM. Seyell and Waltershausen have been necessary in order to find it out. The normal form of Etna is that of a cone of *débris*, placed upon a large dome with long slopes, becoming more and more gentle, and descending gracefully towards the sea. In fact, in most of the eruptions, the lava does not rise as far as the great crater, and breaks through the sides of the volcano so as to flow laterally

over the flanks of Etna. These eruptions, succeeding one another in the course of centuries, bring about the necessary result of gradually enlarging the dome which constitutes the mass of the mountain, thus breaking the uniformity of the lateral talus. The same thing occurs with regard to Vesuvius on the side which faces the sea-coast. There, too, the terminal cone stands on a kind of dome, which has been

Fig. 198.—Section of Vesuvius from South to North.

gradually formed by the layers of lava running one over the other. If Vesuvius continues to be the great volcanic outlet of Italy, and rises gradually into the sky by the superposition of lava and ashes, it cannot fail, some time or other, to assume a form similar to that of the Sicilian giant.

The volcanoes which present cones of almost perfect regularity are those which have their terminal outlet alone in a state of activity, and vomit out a large quantity

Fig. 199.—Section of Etna from West to East.

of ashes or other matter which glides readily over the slopes. Among this class of mountains, those which attain any considerable elevation are distinguished by their majesty from all other peaks. Stromboli, although it is not more than 2,600 feet in height, is one of the wonders of the Mediterranean. From its proud form, it will readily be understood that its roots plunge down into the sea to an enormous depth; the slope of *débris* may be seen, so to speak, prolonged under the water

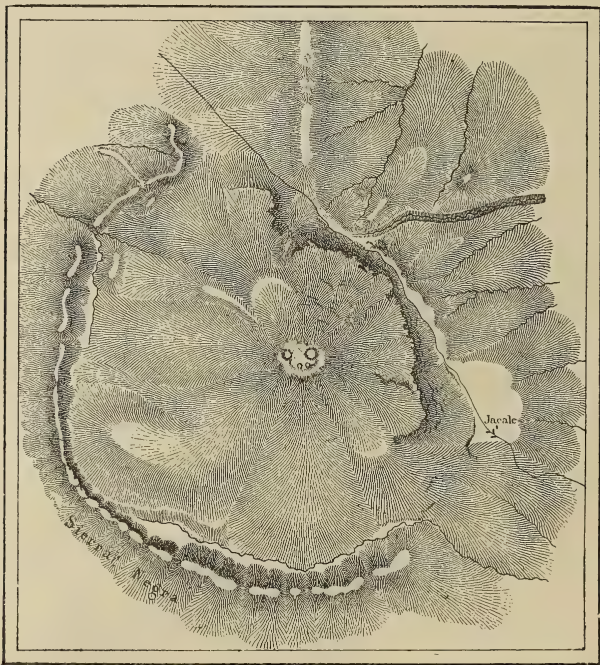
Fig. 200.—Profile of Mount Orizaba.

down to the abysses of 3,000 to 4,000 feet, which the sounding-line has reached at the bottom of the Æolian Sea. At sight of it, one feels as if suspended in the midst of the void, as if the ship was sailing in the air midway up the mountain. This feeling of admiration mingled with dread increases when this great pharos of the Mediterranean is approached during the night over the dark-waved sea. Then the sky above the summit seems all lighted up by the reflection of the lava, and a misty band of clouds and vapour may be dimly seen girdling round the body of the

volcano. In the daytime the impression made is of a different character ; but it is none the less deep, for the real grandeur of Stromboli consists, not so much in the immensity of the mass as in the harmony of its proportions.

Volcanic mountains of an ideal form are those which infant nations have most venerated. Among these sacred mountains are the sublime Cotopaxi of the Andes, Orizaba of Mexico, Mauna-Loa of Hawaii, and Fusi-Yama of Japan. The volcanoes of Java, and chiefly those in the eastern portion of the island, also present a very majestic appearance on account of their isolation. Those on the western side are based upon an undulating plateau, which causes them to lose their appearance of

Fig. 201.—Mount Orizaba.



height; but on the east all the volcanic mountains rise up from verdant plains like islands above the waves of the sea, and command the horizon far and wide with their enormous cones. Between the Merapi and Lavoe mountains lies a depression, the highest ledge of which exceeds the level of the sea by only 312 feet. Between the Lavoe and Villis the plain is 230 feet in height. Lastly, the plains which separate the Villis and Kelœet mountains nowhere attain an elevation of more than 200 feet above the ocean.

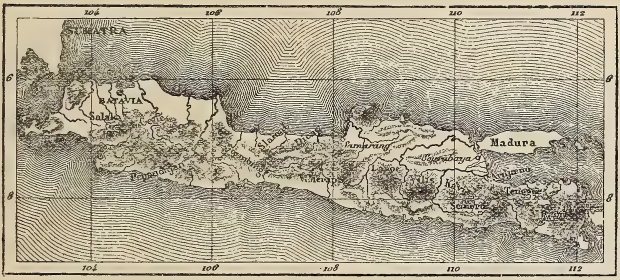
At the eastern extremity of the island the cones are disposed in an oval form encircling a sort of crater, which is no less than 11 miles long in the direction of its axis from north-east to south-west. At the two extremities of this vast circuit,

large as one of the lunar craters, the two volcanoes of Raun and Ijen, or "Great Mountain," are still active.

In the external details of their conformation many of the volcanoes of Java present a regularity of outline which is all the more striking, since they owe it in great part to the monsoon rains, the most destructive agents of the tropical regions. In beating against the mountains, the clouds let fall their burden of moisture on the slopes composed of ashes and loose scoriæ. The latter offer but a slight resistance to the action of the temporary torrents which carry them away, and crumbling down into the plains which surround the base of the volcano, are deposited in long slopes, like those caused by avalanches. In consequence of the fall of all this *débris,* the sides of the mountains are cut out at intervals by ravines or furrows, which gradually widen from the summit to the base of the mountains, and attain a depth of 200, 600, and 660 feet. There are some volcanoes, such as the Sumbing, in which these ravines assume so perfect a regularity, that the whole mountain, with its equidistant furrows and its intermediate walls, resembles a gigantic edifice based upon enormous buttresses, like the nave of a Gothic cathedral.

Formerly the beauty of the island and the fury of its volcanoes were the cause

Fig. 202.—Volcanoes of Java.



of its being altogether dedicated to Siva, the god of destruction; and in the very craters of the burning mountains the worshippers of Terror and Death were in the habit of building their temples. In many spots the ruins of these sanctuaries are discovered in the midst of trees and thickets, which the Arab conquerors have left to grow in the formidable cavities of the volcanoes. Semeroe, the loftiest peak in the island, was the sacred mountain *par excellence;* the Sumbing, which rises in the centre of the island, was the "nail which fastens Java to the earth." Even in our own time some faithful followers of Siva inhabit a sandy plain, more than four miles wide, which was once the crater of the Tengger volcano; every year they proceed solemnly to pour rice on the summit of an eruptive cone into the roaring mouth of the monster. In like manner, in New Zealand, the ever-smoking orifice of Tongariro was considered as the only place worthy of receiving the dead bodies of their great chiefs: when cast into the crater, the heroes went to sleep among the gods.

CHAPTER LXVI.

COMPOSITION OF LAVAS; TRACHYTES; PUMICE-STONE; OBSIDIAN; BASALTS; BASALTIC COLONNADES.

LAVA is the most important product of the volcanic fires. The various kinds of lava differ very much in their external appearance, in the colour of their substance, and in the variety of their crystals, but they are all composed of silicates of alumina or magnesia, combined with protoxide of iron, potash or soda, and lime. When the feldspathic minerals predominate, the rock is generally of a whitish, grayish, or yellowish hue, and receives the name of trachyte. When the lava contains an abundance of crystals of augite, hornblende, or titaniferous iron, it is heavier, of a darker colour, and often more compact; it then takes the generic denomination of basalt. Numerous varieties, diversely designated by geologists, belong to this group.

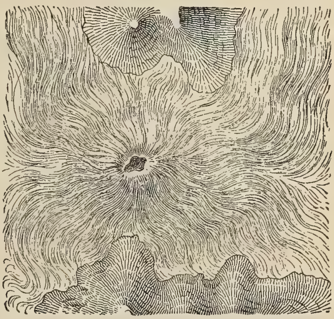
Of all the lavas, trachyte is the least fluid in its form. In many places rocks of this nature have issued from the earth in a pasty state, and have accumulated above the orifice in the shape of a dome, "just like a mass of melted wax." In this way were formed the great domes of Auvergne, the Puys de Dôme and de Sarcouy. In this district the flows of trachytic lava are very inferior in length to the basaltic *cheires;* the most important do not exceed four or five miles in length. At the present day, eruptions of trachyte are much more rare than those of other lavas; so much so, that certain authors class all the trachytic rocks among the formations of anterior ages. It is, however, ascertained that most of the American volcanoes and those of the Sunda Archipelago vomit out lava of this nature; the last eruptions of the Æolian Isles, Lipari, and Volcano, likewise produced only trachyte and pumice-stone.

This latter substance resembles certain white, yellow, or greenish scoriæ, which issue like a frothy dross from the furnaces of our ironworks, and is, like the compact trachyte, of a feldspathic nature. Some mountains are almost entirely composed of it; among others, the Monte Bianco of Lipari, which, viewed from a distance, appears as if covered with snow. Long white flows, like avalanches, fill up all its ravines, from the summit of the mountain to the shore of the Mediterranean; the slightest movement caused by the tread of an animal or a gust of wind detaches from the surface of the slope hundreds of stones, which bound down to the foot of the incline, and are borne away by the waves which bathe the base of the mountain. In the southern part of the Tyrrhenian Sea, and especially in the vicinity of the Lipari (Æolian) Islands, the water is sometimes covered with these floating stones, almost like flakes of foam. In the Cordilleras the currents of fresh water convey

the morsels of pumice to considerable distances. The River Amazon drifts down large quantities of pumice as far as its mouth, more than 3,000 miles from the place where it fell into the river. Bates says that the Indians, who live too far away from the volcanoes even to know of their existence, assert that these stones, floating down the river by the side of their canoes, are assuredly solidified foam.

Among the old basaltic lavas there are some to which the name of *basalt* is more specially applied, which present a columnar disposition with wonderful regularity. These form the enormous monuments, much more imposing than those of man, which seem as if they had been constructed by giant builders, turning their mighty hands to the noble art of architecture, which is still practised, though on a smaller scale, by us their feeble descendants. These magnificent colonnades of basalt are everywhere attributed to giants. In Ireland, on the coast of Antrim, the summits of 40,000 prisms, levelled pretty regularly by the waves of the sea, and resembling a vast paved quay, have received the name of the Giant's Causeway. In Scotland, the beautiful cave of the Isle of Staffa, hollowed out by the action of the waves between two ranges of basaltic shafts, is celebrated as the work of Fingal, the demigod. In the Sicilian Sea, the Faraglioni Isles, or Isles of the Cyclops, situated not far from Catania, at the base of Etna, are looked upon by tradition as the rocks cast by Polyphemus on the ships of Ulysses and his companions. Many of these prisms are from 100 to 160 feet high, and are not less than 6 to 10 feet in thickness. Near Fair Head and the Giant's Causeway some of the shafts connected with the perpendicular cliff of the headland are nearly 400 feet in height. In the Isle of Skye, some of the columns, according to M'Culloch's statement, are still higher. On the other hand, there are also colonnades in miniature, each shaft of which is not more than three-quarters of an inch to an inch from the summit to the base; instances of these are found in the basalts of the hill of Morven in Scotland.

Fig. 203.—Flow of Vitreous Lava at Mauna-Loa.



Some geologists have thought that basaltic columns could not be formed except under the pressure of enormous masses of water; but a comparative study of these rocks in different parts of the world has proved that several beds of lava are arranged in colnmus at heights considerably above the level of the sea. In this colonnade-like formation of lava there is, however, no phenomenon which is entirely peculiar to basalt. Trachyte, also, sometimes assumes this form, and M. Fouqué has discovered a magnificent instance of it in the Island of Milo, in which there is a cliff composed of prismatic shafts 320 feet in height. Masses of mud when dried in the sun, the alluvium of rivers, beds of clay or tufa, and, in general, all matter which, in consequence of the loss of its moisture, passes from a pasty to a solid state, either in a state of nature or in our manufactories and dwellings, likewise assume a columnar structure similar to that of the basaltic lava. In fact, the entire mass, when gradually losing the moisture which swelled out its substance, cannot contract so as to shift the position of all its particles towards the centre; certain points remain fixed, and round each of these the contraction of a portion of the

mass takes place. In basalt, in particular, it is the lower layer which assumes the columnar structure; for these alone cool gently enough to allow the phenomena of contraction to follow the normal course. The highest portion of the mass, being deprived, immediately after its issue from the earth, of the caloric and the steam which filled its pores, is almost immediately transformed into a more or less rough and cracked mass. But this very crust protects the rest of the lava against any radiation, and serves as a covering to the semi-crystalline columns which, by the continual contraction of their particles, are slowly separated from the rest of the mass. When a section of a bed of basaltic lava has been laid bare by the water of a river, the waves of the ocean, or earthquakes, the rough stone of the top layers may be seen lying, with or without any gradual transition, on a forest of prisms, sometimes rudimentary in their shape, but often no less regular than if they had been carved out by the hand of man. Most are of an hexagonal form; others, which were probably subject to less favourable conditions, have four, five, or seven faces; but all are definitely separated from one another by their particles gathering round the central axis. Mr. Poulett Scrope describes a fact which proves the enormous power of this contractile force. The colonnade of Burzet, in Vivarais, contains numerous nodules of olivine, many of which are as large as a man's fist; yet, in spite of their extreme hardness, they have been divided into two pieces, each fixed in one of two adjacent columns. Although the two corresponding surfaces have been polished by the infiltration of water, it is impossible to doubt that the two separate portions were once joined in the same nodule.

As natural philosophers have verified by experiments on various viscous substances, basaltic shafts are always formed perpendicularly to the surface of refrigeration. Now, this surface being inclined, according to the locality, in a diversity of ways, the result is, that the columns may assume a great variety of directions in their position. Although most of them are vertical, on account of the cooling taking place in an upward direction, others, as at St. Helena, take a horizontal direction, and resemble trunks of teees heaped upon a wood-pile. In other places, as at the Coupe d'Ayzac in Auvergne, the columns of a denuded cliff are arranged in the form of a fan, so as to lean regularly on the wall of the cliff as well as on the ground of the valley. At Samoskoe, in Hungary, a sheet of columnar basalt, very small at its origin, spreads out from the top of a rock like the water of a cascade, and hangs suspended over a precipice, resembling a cupola which has lost its base. Elsewhere, masses of basaltic pillars radiate in every direction, like the weapons in an immense trophy of arms.

An exact prismatic form is not, however, the only shape assumed by the cooling lava. The phenomenon of contraction takes place in different ways, according to the nature of the erupted matter, the declivity of the slopes, and all the other surrounding circumstances. Thus, in consequence of the sinking of the rock, most basaltic prisms exhibit at intervals a kind of joint, which gives the columns a resemblance to gigantic bamboos. In some lavas these joints are so numerous, and the edges of the stone are so eaten away by the weather, that the shafts are converted into piles of spheroids of a more or less regular form. At the volcano of Bertrich, in the Eifel, one might fancy them a heap of cheeses; whence comes the name "Cheese Cave," which is given to one of the caverns which opens in the flow of lava. Sometimes, too, crystals scattered about in the midst of the mass have served as nuclei to globular concretions formed of numerous concentric layers. Lastly, many currents of molten matter present a tabular or schistose structure, caused, like that of slate, by the pressure of the superincumbent masses.

CHAPTER LXVII.

SOURCES OF LAVA: STROMBOLI; MASAYA; ISALCO; KILAUEA.—LATERAL CREVICES IN VOLCANOES.—ERUPTION AND MOTION OF LAVA.

ALTHOUGH lava, when cooled, is easy enough to study, it is more difficult to observe with any exactitude the molten matter immediately on its exit from the craters or fissures; besides this, the opportunities for study which are offered to *savants* are sometimes very dangerous. Long years often elapse before an inquirer can notice at his ease, and without fear of sudden explosions, the mouths of Etna or Vesuvius filling up to the brink with boiling lava.

Stromboli is the only volcano in Europe in which this phenomenon occurs regularly at closely-recurring intervals, sometimes of only five minutes, or even more frequently. When an observer stands on the highest edge of the crater, he sees, about 300 feet below him, the waves of a matter which shines like molten iron, and tosses and boils up incessantly; sometimes it swells up like an enormous blister, which suddenly bursts, darting forth eddies of vapour accompanied by solid fragments. For centuries past the lava has never ceased to boil in the cavity of Stromboli, and it is but very rarely that a period of even a few hours elapses without molten matter overflowing. Thus the crater, which, during the day, is white with steam, and during the night red with the glare of the lava, has served as a lighthouse for mariners ever since the first vessel ventured upon the Tyrrhenian Sea.

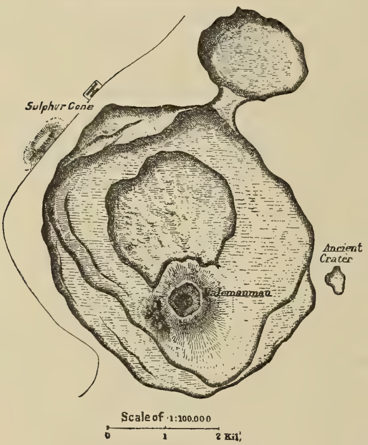
In Nicaragua, to the north of the Great Lake, the volcano of Masaya (or "Devil's Mouth") presents a spectacle similar to that of Stromboli, but grander, and perhaps still more regular. After having remained in a state of repose for nearly two centuries, from 1670 to 1853, the monster—which has received the name it bears from the frightful turbulence of its burning waves—resumed all its former activity. In this crater the enormous bubbles of lava, which ascend from the bottom of the abyss and throw out a shower of burning stones, break forth in a general way every quarter of an hour.

The volcano of Isalco, not far from Sonsonate, in the State of San Salvador, is also one of the most curious on account of its regularity. Its first breaking out was noticed on the 29th of March, 1793, and since this date it has almost always continued to increase in size by throwing outside its cavity ashes and stones. Some of its eruptions, remarkable for their comparative violence, have been accompanied by flows of lava; but, generally, the crater of Isalco confines itself to hurling burning matter to a height of 39 to 46 feet above its crater: explosions follow one another at intervals of every two minutes. The total elevation of the cone of *débris*, above the village of Isalco, being 735 feet, and the slope of the side

of the mass being, on the average, 35 degrees, M. von Seebach, one of the observers of the volcano, has been able to calculate approximately the bulk and regular increase of the mountain. In 1865 the mass of *débris* was about 35,000,000 of cubic yards, giving an increase of about 491,000 cubic yards every year, or 56 cubic yards every hour. The volcano, therefore, might be looked upon as a gigantic hour-glass.

Of all the craters in the world, the one which most astonishes those who contemplate it is the crater of Kilauea, in the Island of Hawaii. This volcanic outlet opens at more than 3,900 feet of elevation on the sides of the great mountain of Mauna-Loa, which is itself crowned by a magnificent funnel-shaped crater, 2,735 yards across from one brink to the other. The elliptical crater of Kilauea is no less than 3 miles in length and 7 miles in circumference. The hollow of this abyss is filled by a lake of lava, the level of which varies from year to year, sometimes rising and sometimes falling like water in a well. In a general way, it lies about 600 to 900 feet below the outer edge, and, in order to study its details, it is necessary to get on to a kind of ledge of black lava which extends round the whole circumference of the gulf; this is the solidified edge of a former sheet of molten matter, similar to those circular benches of ice which, in northern countries, border the banks of a lake, and even in spring still mark the level the water has sunk from. The surface of the sea of fire is generally covered by a thick crust over its whole extent; here and there the red lava-waves spring up like the water of a lake through the broken ice. Jets of vapour whistle and hiss as they escape, darting out showers of burning scoriæ, and forming cones of ashes on the crust, 60 to 100 feet in height, which are so many volcanoes in miniature. Intense heat radiates from the immense crater, and a kind of hot blast makes its way through all the chinks in the vertical walls of the sides. In the midst of the hot vapours, one feels as if lost in a vast furnace. During the night-time an observer might fancy himself surrounded with flames; the atmosphere itself, coloured by the red reflection of the vent-holes of the volcano, seems to be all on fire.

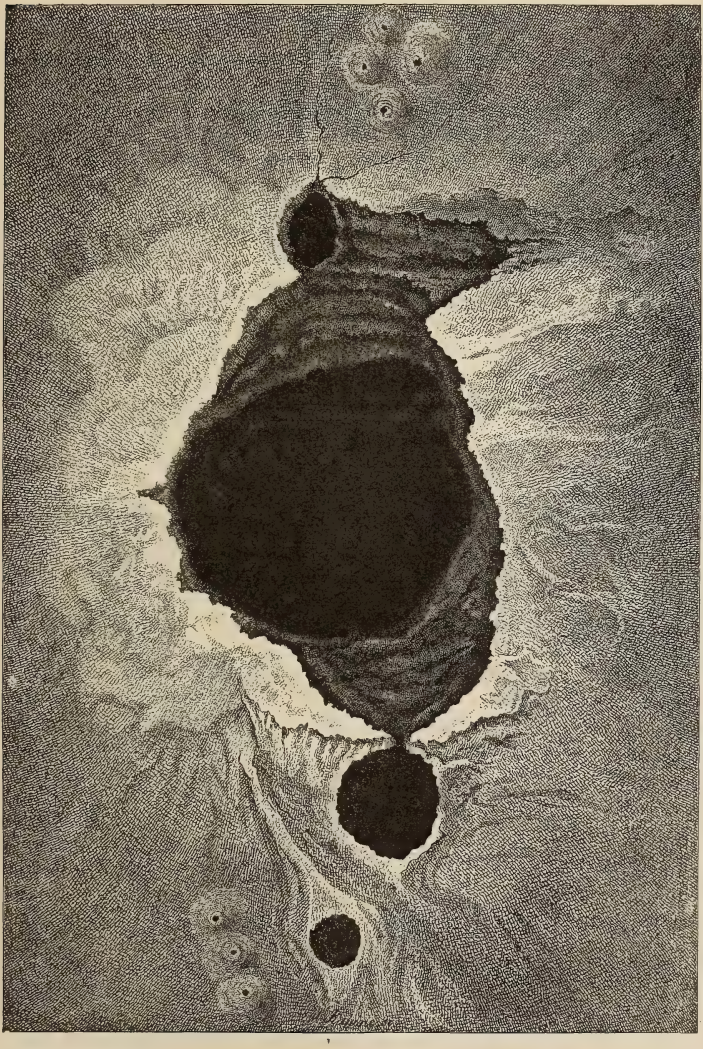
Fig. 204.—Craters of Kilauea.



The level of the fire-lake of Kilauea is incessantly changing. In proportion as fresh lava issues forth from the subterranean furnace, the broken crust affords an outlet to other sheets of molten matter and fresh heaps of scoriæ, and gradually the boiling mass rises from ledge to ledge, and ultimately reaches the upper edge of the basin. Sooner or later, however, the level rapidly sinks. The fact is, that the burning mass contained in the depths of the abyss gradually melts the lower walls of solid lava; these walls ultimately give way at some weak points in their circumference, a crevice is produced in the outer face of the volcano, and the liquid matter "drawn off," like wine from a vat, rushes through the opening made for it. The flow increases the orifice by the action of its weight on the sill of the opening, and by melting the rocks which oppose its passage, and then running down over the

slopes, flows into the sea, forming promontories on the shore. In 1840 the crater was full to the brink, when a crack suddenly opened in the side of the mountain.

Fig. 205.—Crater of Mauna-Loa.

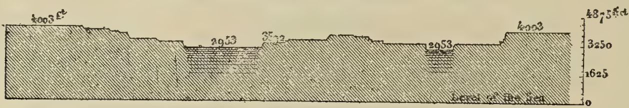


This fissure extended to a distance of 131 feet from its starting-point, and vomited forth a stream of lava 37 miles long and 16 miles wide, which entirely altered the

outline of the sea-coast, and destroyed all the fish in the adjacent waters. Mr. Dana estimated the total mass of this enormous flow as equal to 7,200,000 cubic yards; that is, to a solid body fifty times as great as the quantity of earth dug out in cutting through the Isthmus of Suez. The enormous basin of Kilauea, 1,476 feet deep, remained entirely empty for some time, and the former lake of lava left no other trace of its existence than a solid ledge like those which had been formed at the time of previous eruptions. Since this date the great cauldron of lava has been several times filled and several times emptied, either altogether or in part.

Almost all the volcanoes which rise to a great height get rid, like Kilauea, of their overflow of lava through fissures which open in their side walls. In fact, the column of molten matter which the pressure of the gas beneath raises in the pipe of the crater is of an enormous weight, and every inch it ascends towards the mouth of the crater represents an expense of force which seems prodigious. The more or less hypothetical calculations which have been made as to the degree of pressure necessary for the steam to be able to act on the lava-furnace lead to the belief that the outlet-conduits of volcanoes, and consequently the mass of liquid stone to be lifted, are not less than nine miles in depth. Various geologists—amongst others, Sartorious von Waltershausen, the great explorer of Etna—believe that the volcano-shafts are of a still more considerable depth. The rocks of the terrestrial surface, limestone, granite, quartz, or mica, are of a specific gravity two and a half times superior to that of water, whilst the planet itself, taken as a whole, weighs nearly

Fig. 206.—Section across the Craters of Kilauea.



five and a half times as much as the same mass of distilled water; the density of the interior layers must therefore increase from the circumference to the centre. With regard to the proportion of this increase, it is established by a calculation, the whole responsibility of which must rest upon its authors. Baron Waltershausen has ascertained, by means of a great number of weighings, that the lava of Etna and that of Iceland have a specific gravity of 2·911. The presumed consequence of this fact is that the rocks thrown out by the volcanoes of Sicily and Iceland proceed from a depth of 77 to 78 miles (?). Thus, the shaft which opens at the bottom of the crater of Etna would be no less than 77 miles deep, and the lava which boils in this abyss would be lifted by a force of 36,000 atmospheres, an idea altogether incomprehensible by our feeble imaginations. There would, then, be nothing astonishing in the fact that a mass of lava, which is sufficiently heavy to balance a pressure of this kind, should, in a great many eruptions, melt and break through the weaker parts of its walls, instead of ascending some hundreds or thousands of feet higher so as to run out over the edge of the upper crater.

When the side of the mountain opens, and affords a passage to the lava, the fissure is always perceptibly vertical, and those which are continued to the summit pass through the very mouth of the volcano. In a general way these fissures of eruption are of considerable length, and are sufficiently wide to form an impassable precipice. Before these fissures become obliterated by the lava, or by other *débris* —such as the snow and earth of avalanches—they may be traced out by the eye as

deep furrows hollowed out on the mountain-side. In 1669 the lateral fissure of Etna extended over more than two-thirds of the southern side—from the plains of Nicolosi to the terminal gulf of the great crater. In like manner, in the Isle of Jan Mayen, the volcano of Beerenberg, 7,531 feet high, presents from top to bottom a long depression filled up with snow, which is nothing else than a fissure of eruption. On other mountains, especially in Montserrat, Guadaloupe, and Martinique, these fissures have assumed such dimensions that the peaks themselves have been completely split in two.

Through outlets of this kind the lava jets out, first making its appearance at the upper part, where the declivity is generally steeper, then springing out below on the more gentle slopes of the lower regions of the mountain.

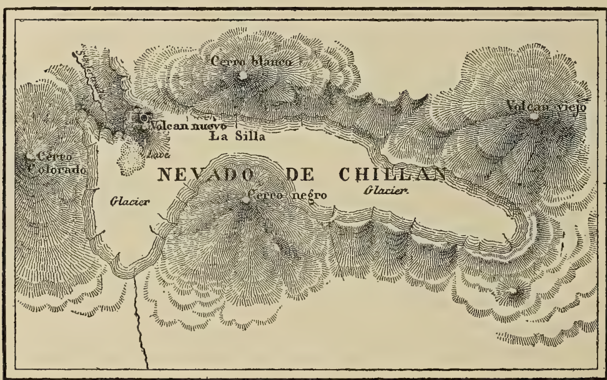
At the source itself the lava is altogether fluid, and flows with considerable speed—sometimes, on steep slopes, faster than a horse can gallop; but the course of the molten stone soon slackens, and the liquid, hitherto dazzling with its light, is covered by brown or red scoriæ, like those of iron just come out of a furnace. These scoriæ come together, and, combining, soon leave no interstices between them beyond narrow vent-holes, through which the molten matter escapes. The scoriæ then form a crust, which is incessantly breaking with a metallic noise, but gradually consolidates into a perfect tunnel round the river of fire; this is the *cheire*, thus named on account of the asperities which bristle on its surface. Any one may safely venture on the arch-shaped crust, although only a few inches above the mass in a state of fusion, without any fear of being burnt—just as in winter we trust ourselves on the sheets of ice which cover a running stream. The pressure of the lava succeeds in breaking through its shell only at the lower parts of its flow, in spots where the waves of burning stone fall with all their weight. Then the envelope is suddenly ruptured, and the mass springs out like water from a sluice, pushing before it the resounding scoriæ, and swelling out gently in the form of an enormous blister; then it again becomes covered with a solid crust, which is again broken through by a fresh effort of the lava. Thus the river, surrounding itself with dikes which it constantly breaks through, gradually descends over the slopes, terrible and inexorable, so long as the original stream does not cease to flow. The only means of diverting the current is to modify the incline in front of it—either by opposing obstacles to it to throw it to either side, or by preparing a road for it by digging deep trenches, or by opening up above some lateral outlet for the pent-up lava. In 1669, at the time of the great eruption which threatened to swallow up Catania, all these various means were adopted in order to save the town. On one side the inhabitants worked at consolidating the rampart, and placed obstacles across the path of the current to turn it towards the south. Other workmen, furnished with shovels and mattocks, ascended along the edge of the flow, and, in spite of the resistance offered by the peasants, tried to pierce through the shell of scoriæ, and thus, by tapping the stream, to open fresh outlets for the molten matter. These means of defence partly succeeded, and the terrible current which, at its source near Nicolosi, had been able to melt and pierce through the volcanic cone of Monpilieri at its thickest point (this cone standing in its path), was turned from its course towards the centre of Catania, and destroyed nothing but the suburbs.

On lofty mountains in a state of eruption, the masses of snow and ice, which are covered by the fiery currents which issue from the volcanic fissures, do not always melt, and some have been preserved under the scoriæ for centuries, or even thousands of years. Lyell has discovered them under the lava of Etna, American geolo-

gists under the masses thrown out by the crater of Mount Hooker, Darwin under the ashes in Deception Island, in Tierra del Fuego, M. Philippi under the flows of the volcano Nuevo de Chillan, which, in 1861, erupted through a glacier. There every bed of snow which falls during the winter remains perfect under the coat of burning dust which is ejected from the outlet of eruption, and sections made through the mass of *débris* show for a great depth the alternate black and white strata of the volcanic ashes and snow. In 1860 the crater of the mountain of Kutlagaya, in Iceland, hurled out simultaneously into the air lumps of lava and pieces of ice, all intermingled together.

In like manner, the immense flows of lava in Iceland have left in a perfect state of preservation the trunks of the *Sequoias*, and other American trees, which adorned the surface of the island during the ages of the Tertiary epoch, at a time when the mean temperature of this country was 48° (Fahr.), that is 42° to 44° above that which it is at present. Although the radiation from the lava is so slight that it neither melts the ice nor burns the trunks of buried trees, yet, on the other

Fig. 207.—Nevado de Chillan.



hand, the heat and fluidity of the lava are maintained in the central part of the flow for a very considerable number of years. Travellers state that they have found deeply-buried lava which was still burning after it had remained for a century on the mountain-side.

CHAPTER LXVIII.

VOLCANIC PROJECTILES.—EXPLOSIONS OF ASHES.—SUBORDINATE VOLCANOES.—MOUNTAINS REDUCED TO DUST.—FLASHES AND FLAMES PROCEEDING FROM VOLCANOES.

THE lava swelling up in enormous blisters above the fissures from which it flows in a current over the slopes is far from being the only substance ejected from volcanic mountains. When the pent-up vapour escapes from the crater with a sudden explosion, it carries with it lumps of molten matter, which describe their curve in the air, and fall at a greater or less distance on the slope of the cone, according to the force with which they were ejected. These are the volcanic projectiles, the immense shower of which, traced in lines of fire on the dark sky, contribute so much during the night-time to the magnificent beauty of volcanic eruptions. These projectiles have already become partially cooled by their radiation in the air, and when they fall are already solidified on the outside, but the inside nucleus remains for a long time in a liquid or pasty state. The form of these projectiles is often of an almost perfect regularity. Each sphere is in this case composed of a series of concentric envelopes, which have evidently been arranged in the order of their specific gravity during the flight of the projectile through the air. The dimensions of these projectiles vary in each eruption; some of them are one or more yards in thickness; others are nothing but mere grains of sand, and are carried by the wind to great distances.

In most eruptions, these balls of lava, still in a fluid and burning state, constitute but a small part of the matter thrown out by the mountain. The largest proportion of the stones ejected proceed from the walls of the volcano itself, which break up under the pressure of the gas, and fly off in volleys, mingled with the products of the new eruption. This is the origin of the dust or ashes which some craters vomit out in such large quantities, which, too, are the cause of such terrible disasters.

When the impetus of the gas confines itself to forming a fissure in the side of the mountain, the fragments of rocks which are broken up and reduced to powder are comparatively small in quantity. They are projected in clouds out of the fissure, and falling like hail round the orifice, are gradually heaped up in the form of a cone on the side of the mountain from which they arose. In Europe the enormous circumference of Etna presents more than 700 of these subordinate volcanoes, some scarcely higher than an Esquimaux hut, and others, like the Monte-Rossi, Monte-Minardo, Monte-Ilici, several hundred yards high, and more than half-a-mile wide at the base. There are some which are entirely sterile or

covered only by a scanty vegetation of broom, and are marked out by a red, yellow, or even black colour on the main body of Etna; those situated on the lower slopes are covered with trees or planted with vines, and sometimes contain admirable crops in the very cavity on their summit. These cones of ashes, springing up like a progeny on the vast sides of their mother-mountain, give to Etna a singular appearance of vital personality and of creative energy. The same phenomenon occurs on the volcanoes of Hawaii, which carry on their declivities thousands of subordinate cones.

In the formation of these hillocks a real division of labour takes place. The rocks and heavier stones fall either on the edge of the crater or in the gulf itself. The ashes and light dust are shot up to a much greater height, and, hurried along by the impulse of the wind, fall far and wide, like the chaff of corn winnowed in a threshing-floor. Thus the slope of the cone towards which the wind directs the ashes is always more elongated, and rises to a greater height on the edge of the crater. On Etna, where the wind generally blows in the direction of west to east, the eastern slope of the hillocks is more developed than on the opposite side. It must, perhaps, be attributed to the action of the wind blowing on the heights, and

Fig. 208.—Regular Cone of Ashes.

Fig. 209.—Cone of Ashes modified by the Wind.

not, as Siemsen, the geologist, supposes, to the obliquity of the shaft of the crater, that all the scoriæ and ashes fall to the north of the orifice of the volcano Nuevo de Chillan, in Chili.

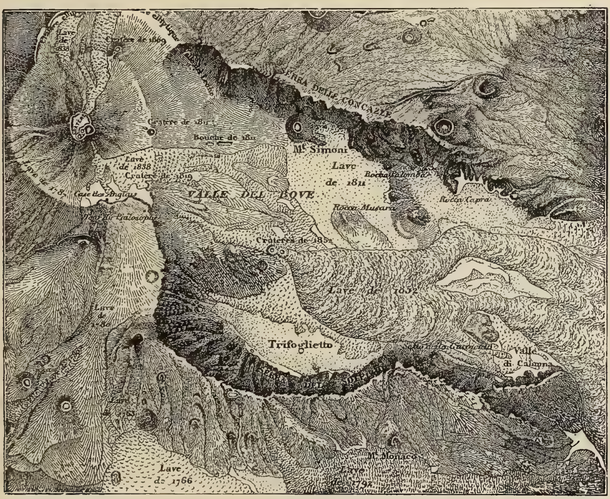
The phenomena which take place when the ashes issue from the mouth of the crater itself do not differ from those which are observed at the outlets in fissures. In the former case, however, the mass of rocks reduced to powder is so considerable that the rain of ashes assumes all the proportions of a cataclysm. It has sometimes happened that, during a paroxysm of volcanic energy, the whole summit of a mountain, for a depth of several thousands of feet, has been hurled into the air, mingled with a cloud of vapour and the smoke of burning lava. Thus, Etna, if we are to believe Ælianus, was once much loftier than it is in our time, and on the north of the present terminal cone there may, in fact, be noticed a kind of platform which seems to have been the base of a summit twice as high as the present crest. The whole Val del Bove is probably an empty space left by the disappearance of a former cone. Again, in 1879, the cone was diminished in height by at least 40 feet, so that its present elevation is only 9,960 feet. At the same time, according to Silvester's measurements, the circuit of the crater was increased from 4,330 to 6,000 feet.

With regard to Vesuvius, it is known that, in the year 79 of the present era, the whole of that part of the mountain which was turned towards the sea was reduced to powder, and that the *débris* of the cone, nothing of which now remains except the semicircular enclosure of La Somma, buried three towns and a vast extent of plain. The ashes and dust, mingled with white vapour rising in thick eddies, ascended in a column to a point far above the summit of the volcano, until, having reached those regions of the atmosphere where the rarefied air could no longer sustain them, they spread out into a wide umbrella-like shape, the falling

dust of which obscured the sky. Pliny the Younger compared this vault of ashes and smoke to the foliage of an Italian pine curving at an immense height over the mountain. Since this memorable epoch the height of the column of vapour has been measured which has issued from Vesuvius at the time of several great eruptions, and it has been sometimes found that it reached 23,000 to 26,000 feet; that is, six times higher than the summit of the volcano itself.

One of these explosions of entire summits which caused most terror in modern times was that of the volcano of Coseguina, a hillock of about 500 feet high, situated on a promontory to the south of the Bay of Fonseca, in Central America. The

Fig. 210.—Cone of Etna and Val del Bove.

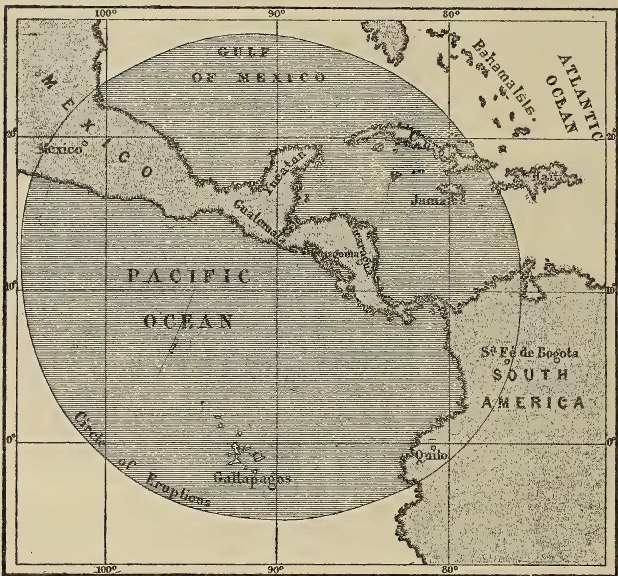


débris hurled into the air spread over the sky in a horrible arch several hundreds of miles in width, and covered the plains, for a distance of 25 miles, with a layer of dust at least 16 feet thick. At the very foot of the hill the headland advanced 787 feet into the bay, and two new islands, formed of ashes and stones falling from the volcano, rose in the midst of the water, several miles away. Beyond the districts close round the crater, the bed of dust, which fell gradually, became thinner, but it was carried by the wind more that 40 degrees of longitude towards the west, and the ships sailing in those waters penetrated with difficulty the layer of pumice-stone spread out on the sea. To the north, the rain of ashes was remarked at Truxillo, Honduras, and at Chiapas, in Mexico; on the south, it reached Carthagena, Santa Martha, and other towns of the coast of Grenada; to the east, being carried by the counter-current of the trade winds, it fell on the plains of St. Ann's, in Jamaica, at a distance of 800 miles. The area of land and water on which the dust descended must be estimated at 1,500,000 square miles, and the mass of matter vomited out could not have been less than 65,000 million cubic yards.

The uproar of the breaking up of the mountain was heard as far as the high plateaux of Bogota, situated 1,025 miles away in a straight line. Whilst the for-

midable cloud was settling down round the volcano, thick darkness filled the air. For forty-three hours nothing could be seen except by the sinister light of the flashes darting from the columns of steam, and the red glare of the vent-holes opening in the mountain. To escape from this prolonged night, the rain of ashes, and the burning atmosphere, the inhabitants who dwelt at the foot of Coseguina fled in all haste along a road running by the black water of the Bay of Fonseca. Men, women, children, and domestic animals travelled painfully along a difficult path, through quagmires and marshes. So great, it is said, was the terror of all animated beings during this long night of horror, that the animals themselves—such as monkeys, serpents, and birds—joined the band of fugitives, as if they recognised in man a being endowed with intelligence superior to their own.

Fig. 211.—Eruption of Coseguina.



A large number of volcanoes have diminished in height, or have, indeed, entirely disappeared, in consequence of explosions, which reduced their rocks to powder, and distributed them in thick sheets on the ground adjacent. Mount Baker, in California, and the Japanese volcano of Unsen, have thus raised the level of the surrounding plains at the expense of a diminution in their own volume. In 1638, the summit of the peak of Timor, which might be seen like a lighthouse from a distance of 270 miles, exploded, and blew up into the air, and the water collecting, formed a lake in the enormous void caused by the explosion. In 1815, Timboro, a volcano in the Island of Sumbara, destroyed more men than the artillery of both the armies engaged on the battle-field of Waterloo. In the Island of Sumatra, 550 miles to the west, the terrible explosion was heard, and, for a radius of 300 miles round the mountain, a thick cloud of ashes, which obscured the sun, made it

dark like night even at noonday. This immense quantity of *débris*, the whole mass of which was, it is said, equivalent to thrice the bulk of Mont Blanc—that is, 2,358,000 millions of cubic yards (?)—fell over an area larger than that of Germany. The pumice-stone which floated in the sea was more than a yard in thickness, and it was with some difficulty that ships could make their way through it. The popular imagination was so deeply impressed by this cataclysm, that at Bruni, in the Island of Borneo, whither heaps of the dust vomited out by Timboro, 870 miles away to the south, had been carried by the wind, they date their years from "the great fall of ashes." It is the commencement of an era for the inhabitants of Bruni, just as the flight of Mahomet was for the Mussulmans.

The friction of the steam against the innumerable particles of solid matter which

Fig. 212.—Eruption of Timboro.

are darted out into the air is the principal cause of the electricity which is developed so plentifully during most volcanic eruptions. In consequence of this friction, which operates simultaneously at all points in the atmosphere which are reached by the volcanic ashes and vapour, sparks flash out which are developed into lightning. The skies are lighted up not only by the reflection from the lava, but also by coruscations of light which dart from amidst the clouds. When the vast canopy of vapour spreads over the summit of the mountains, numerous spirals of fire whirl round on each side of the clouds, which, as they unroll, resemble the foliage of a gigantic tree. Doubtless, also, the encounter of two aërial currents may contribute to produce lightning in the columns of vapour; yet, when the latter are slightly mingled with ashes, they are rarely stormy.

Although the evolution of electricity in the columns of vapour and ashes vomited

out by volcanoes has never been called in question, the appearance of actual flames at the time of volcanic eruptions was for a long time disputed. M. Sartorius von Waltershausen, the patient observer of Etna, has maintained that neither this mountain, nor Stromboli, nor any other volcano, has ever presented among its phenomena any fire properly so called, and that the supposed flames were nothing more than the reflection of the red or white lava that was boiling in the crater. On the other hand, Elie de Beaumont, Abich, and Pilla positively assert that they have seen light flames on the summit of Vesuvius and Etna. It would, however, be very natural to believe that inflammable gases might be liberated and take fire at the outlet of those immense shafts, which place the great subterranean laboratory of lava in communication with the outer air.

This question was, however, resolved in the affirmative at the time of the eruption of Santorin in 1866, and popular opinion was right in opposition to most men of science. All those who were able to witness, at its commencement, the upheaval of the lava at Cape George and Aphroessa, have certified to the appearance of burning gas dancing above the lava, and even on the surface of the sea. All round the upheaved hillocks, bubbles of gas breaking forth from the waves became kindled as they came in contact with the burning mass, and were diffused over the water in long trains of white, red, or greenish flames, which the breeze alternately raised or beat down; sometimes a smart puff of wind put out the fire, but it soon recommenced to run over the breakers; by approaching it carefully, fragments of paper might be burnt in it, which lighted as they dropped. On the slopes of the volcano of Aphroessa, fire, rendered of a yellowish hue by salts of soda, sprung out from all the fissures, and rose to a height of several yards. On the rather older lava of Cape George the trains of flame were less numerous; there, however, bluish glimmers might be seen flitting about in some spots over the black ridges of lava.

Added to this, are not the flames at Bakou, on the coast of the Caspian Sea, produced by the volcanic action of the ground? The "growing mountains" in the neighbourhood are mud-volcanoes, and we must, doubtless, attribute to the same subterranean activity the production of the hydrogen gas which burns in an "eternal flame" in the temples of the Parsi. During some of the evenings in autumn, when the weather is fine and the sun has heated the surface of the ground, the flames occasionally make their appearance on the hills, and for several hours may be seen the marvellous spectacle of fire stretching along the country, without burning the ground, and even without scorching a blade of grass.

CHAPTER LXIX.

STREAMS OF MUD EJECTED BY CRATERS.—MUD-VOLCANOES.

NEXT to lava and ashes, streams of water and mud are the most considerable products of volcanic activity, and the catastrophes which they have caused are perhaps amongst the most terrible which history has to relate. By means of these sudden deluges, towns have been swept away or swallowed up, whole districts dotted over with habitations have been flooded with mud or converted into marshes, and the entire face of nature has been changed in the space of a few hours.

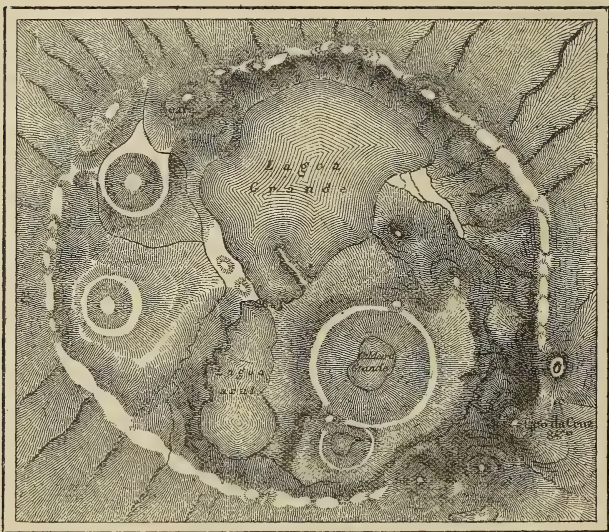
The liquid masses which descend rapidly from the mountain height do not always proceed from the volcano itself. Thus the local deluge may be caused by a rapid condensation of large quantities of steam which escape from the crater and fall in torrents on the slopes. A phenomenon of this kind must evidently take place in a great many cases, and it was doubtless by a cataclysm of this kind that the town of Herculaneum, at the foot of Vesuvius, was buried. As regards the lofty snow-clad volcanoes of the tropical and temperate zones, and also those of the frozen regions, the torrents of water and *débris*—the "water-lava," as the Sicilians call them—may be explained by rapid melting of immense masses of snow and ice, with which the burning lava, the hot ashes, or the gaseous emanations of the volcanic furnace have come in contract. Thus, in Iceland, after each eruption, formidable deluges, carrying with them ice, scoriæ, and rocks, suddenly rush down into the valleys, sweeping away everything in their course. These liquid avalanches are the most terrible phenomena which the inhabitants of the island have to dread. They show three headlands formed of *débris*, which the body of water descending from the sides of Kutlugaya in 1766 threw out far into the sea, in a depth of 246 feet of water.

Other deluges no less formidable are caused by the rupture of the walls which pen back a lake in the cavity of a former crater, or by the formation of a fissure which affords an outlet to liquid masses contained in subterranean reservoirs. It would be difficult to explain otherwise the mud-eruptions of several trachytic volcanoes of the Andes—Imbambaru, Cotopaxi, and Carahuarizo. In fact, the mud (*lodozales*) which comes down from these mountains often contains a large quantity of organized beings, aquatic plants, infusoria, and even fish, which could only have lived in the calm waters of a lake. Of this kind is the *Pimelodes cyclopum*, a little fish of the tribe of the *Siluridæ*, which, according to Humboldt, has hitherto been found nowhere except in the Andes caverns, and in the rivulets of the plateau of Quito. In 1691 the volcano of Imbambaru vomited out, in combination with mud and snow, so large a quantity of these remains of organisms that the air was

contaminated by them, and miasmatic fevers prevailed in all the country round. The masses of water which thus rush down suddenly into the plains amount sometimes to millions, or even thousands of millions, of cubic yards.

Although, in some cases, these eruptions of mud and water may be looked upon as accidental phenomena, they must, on the contrary, as regards many volcanoes, be considered as the result of the normal action of the subterranean forces. They are, then, the waters of the sea or of lakes which, having been buried in the earth, again make their appearance on the surface, mingled with rocks which they have dissolved or reduced to a pasty state. A remarkable instance of these liquid eruptions is that presented by Papandayang, one of the most active volcanoes in Java. In 1792 this mountain burst, the summit was converted into dust and disappeared, and the *débris*, spreading far and wide, buried forty villages. Since this epoch a

Fig. 213.—Crater of Sete Cidades.



copious rivulet gushes out in the very mouth of the crater, at a height of 7,710 feet, and runs down into the plain, leaping over the blocks of trachyte. Round the spring, pools of water fill all the clefts in the rocks, and boil up incessantly under the action of the hot vapours which rise in bubbles; here and there are funnel-shaped cavities, in which black and muddy water constantly ascends and sinks with the same regularity as the waves of the sea; elsewhere, muddy masses slowly issuing from small craters flow in circular slopes over mounds of a few inches or a yard in height; lastly, jets of steam dart out of all the fissures with a shrill noise, making the ground tremble with the shock. All these various noises, the roaring of the cascades, the explosion of the gaseous springs, the hoarse murmur of the mud-volcanoes, the shrill hissing of the *fumerolles*, produce an indescribable uproar, which is audible far away in the plains, which, too, has given to the

volcano its name of Papandayang, or "Forge," as if one could incessantly hear the mighty blast of the flames and the ever-recurring beating of the anvils.

In volcanoes of a great height it is rarely found that eruptions of water and mud are constant, as in the Papandayang; but temporary ejections of liquid masses are frequent, and there are, indeed, some volcanoes which vomit out nothing but muddy water. The volcano of Aqua (or *water*), the cone of which is gently inclined like that of Etna, and rises to about 13,000 feet in height, into the regions of snow, has never vomited anything but water; and it is, indeed, stated that lava and other volcanic products are entirely wanting on its slopes. Yet, in 1541, this prodigious intermittent spring hurled into the air its terminal point (*coronilla*), and poured over the plains at its base, and over the town of Guatemala, so large a quantity of water, mingled with stones and *débris*, that the inhabitants were compelled to fly with the greatest haste, and to reconstruct their capital at the foot of the volcano of Fuego. This new neighbour, however, showed that he was as much or more to be dreaded than their former one, for the violent eruptions from the mountain compelled the inhabitants of the second town to again migrate, and to rebuild their capital at a point 20 miles to the north-west.

Several volcanoes in Java and the Philippines also give vent, during their eruptions, to large quantities of mud, sometimes mingled with organic matter in such considerable proportions that they have been utilised as fuel. In 1793, a few months after the terrible eruption of Unsen, in the island of Kiusiu, an adjacent volcano, the Miyi-Yama, vomited, according to Kampfer, so prodigious a quantity of water and mud that all the neighbouring plains were inundated, and 53,000 people were drowned in the deluge; unfortunately, we have no historical details of this catastrophe. Of all the eruptions of mud, the best known is that of Tunguragua, a volcano in Ecuador, which rises to the south of Quito to 16,400 feet in height. In 1797, at the time of the earthquake of Riobamba, a whole side of the mountain sank in an immense downfall, with the forests which grew on it; at the same time, a flow of viscous mud issued from the fissures at its base, and rushed down into the valleys. One of these currents of mud filled up a winding defile, which separated two mountains, to a depth of 650 feet, over a width of more than 1,000 feet, and damming up the rivulets at their outlet from the side valleys, kept back the water in temporary lakes: one of these sheets of water remained for eighty-seven days.

The volcano mud, therefore, has this point of resemblance with the lava—that it sometimes flows out through the crater, as on Papandayang; sometimes through side craters, as on Tunguragua. Doubtless, when the volcanic muds have been better studied, we shall be enabled to trace the transition which takes place by almost imperceptible degrees between the more or less impure water escaping from volcanoes, and the burning lava more or less charged with steam. This transition is, however, already noticed in the ancient matter which the water has carried down and deposited in strata at the foot of volcanic mountains. These rocks, known under the name of *tufa*, *trass*, or *peperino*, are nothing but heaps of pumice, scoriæ, ashes, and mud, cemented together by the water into a species of mortar or conglomerate, and gradually solidified by the evaporation of the humidity which they contained. Of this kind, for instance, is the hardened stone which, for eighteen centuries, has covered the city of Herculaneum with a layer of 50 to 150 feet in thickness. Among rocks of various formations there are but few which exhibit a more astonishing diversity than the tufas. They differ entirely in appearance and physical qualities, according to the nature of the materials which have formed them,

the quantity of water which has cemented them, the greater or less rapidity with which their fall and desiccation take place; lastly, the number and distribution of the chinks which are produced across the dried mass, and have been filled up with the most different substances. Many kinds of tufa resemble the most beautiful marble.

The small hillocks, which are specially called mud-volcanoes, or *salses*, on account of the salts which are frequently deposited by their waters, are cones which differ only in their dimensions from the mighty volcanoes of Java or the Andes. Like these great mountains, they shake the ground, and rend it, in order to discharge their pent-up matter; they emit gas and steam in abundance, add to their slopes by their own *débris*, shift their places, change their craters, throw off their summits in their explosions; lastly, some of these *salses* are incessantly at work, whilst others have periods of repose and activity. In nature, transitions merge into one another so perfectly, that it is difficult to discover any essential difference between a volcano and a *salse*, and between the latter and a thermal spring.

Mud-volcanoes exist in considerable numbers on the surface of the earth, and, like the volcanoes of lava, the neighbourhood of the sea-coast is the principal locality where we find their little cones. In Europe, the most remarkable are those which are situated at the two extremities of the Caucasus, on the coasts of the Caspian Sea, and on both sides of the Straits of Yenikale, which connect the Sea of Azof with the Black Sea. On the east, the mud-springs of Bakou are especially distinguished by their combination with inflammable gases; on the west, those of Taman and Kertch flow all the year round, but especially during times of drought, pouring out large quantities of blackish mud. One of these mud-volcanoes, the Gorela, or Kuku-Oba, which, in the time of Pallas, was called the "Hell," or Prekla, on account of its frequent eruptions, is no less than 246 feet in height, and from this crater, which is perfectly distinct, muddy streams have flowed, one of which was 2,624 feet long, and contained about 850,000 cubic yards.

CHAPTER LXX.

VOLCANIC THERMAL SPRINGS.—GEYSERS.—SPRINGS IN NEW ZEALAND.—FUMEROLLES.—SOLFATARAS.—CRATERS OF CARBONIC ACID.

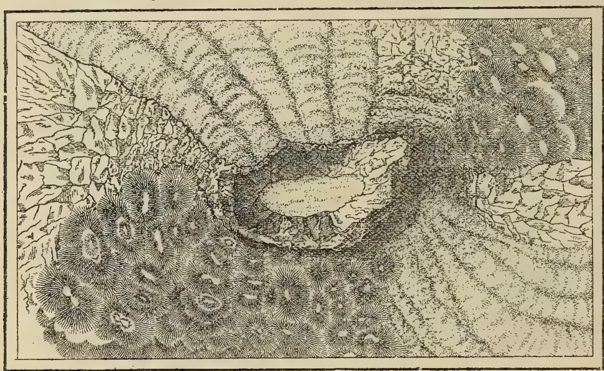
VOLCANOES, both of lava and mud, all have, either on their sides or in the vicinity of their base, thermal springs, which afford an outlet to their surplus water, gas, and vapour. Most even of those mountains which are at present tranquil, but which were once centres of eruption, continue to manifest their activity by vapours and gas, like furnaces in which the flames are extinct, but the smoke is still rising. Although lava and ashes no longer make their escape from the crater or lateral fissures, yet numerous *fumerolles* and hot springs, formed by the condensation of the steam, generally serve as a vehicle for the gas pent up in the depths of the mountain. We may reckon by hundreds and thousands the "geysers," the "vinegar springs," and other thermal springs in countries once burning with volcanoes, the fires of which are extinct, or at least quiescent for a period more or less protracted. Thus the former volcanoes of Auvergne; the mountains of the Eifel, on the Rhine, the craters of which contain nothing but lakes or pools; the Demavend, with its mouth filled up with snow—all still exhale here and there, through springs and *fumerolles*, as it were, a feeble breath of their once mighty vitality.

The volcanic regions of the earth where thermal springs gush out are very numerous: in Europe we have Sicily, Iceland, Tuscany, and the peninsula of Kertch; in America—that land so rich in volcanoes—the springs warmed by subterranean vapour are still more numerous, and there are some on the sides of the volcano Nuevo de Chillan which gush out through a thick bed of perpetual snow. A lateral gorge of the valley of Napa, in California, called the "Devil's Cañon," may be quoted as one of the most striking examples of the active production of thermal waters. The narrow ravine, filled with vapour rising in eddies, opens on the side of a red and bare mountain, that one might fancy was scorched by fire. The entry to the ravine follows the course of a rivulet, the boiling waters of which are mingled with chemical substances horrible to the taste. Innumerable springs—some sulphureous, others charged with alum or salt—gush out at the base of the rocks. There are both warm and cold springs, and hot and boiling; some are blue and transparent, others white, yellow, or red with ochre. In a cavity which is called the "Sorcerer's Caldron" a mass of black and fetid mud boils up in great bubbles. Higher up, the "Devil's Steamboat" darts out jets of gaseous matter, which issue puffing from a wall of rock: *fumerolles* may be seen by hundreds on the sides of the mountain. All these various agents either murmur, whistle,

rumble, or roar, and thus a tempest of deafening sounds incessantly fills the gorge. The burning ground, composed of a clayey mud—in one spot yellow with sulphur, and in another white with chalk—gives way under the feet of the traveller who ventures on it, and gives vent to puffs of vapour through its numberless cracks. The whole gorge appears to be the common outlet of numerous reservoirs of various mineral waters, all heated by some great volcanic furnace.

The ravine of Infernillo (Little Hell), which is situated at the base of the volcano of San Vincente, in the centre of the Republic of San Salvador, presents phenomena similar to those of the "Devil's Cañon." There, too, a multitude of streams of boiling water gush from the soil, which is calcined like a brick, and eddies of vapour spring from the fissures of the rock with a noise like the shrill whistle of a locomotive. The most considerable body of water issues from a fissure 32 feet in width, which opens under a bed of volcanic rocks at a slight elevation above the bottom of the valley. The liquid stream, partially hidden by the clouds of vapour which rise from it, is shot out to a distance of 130 feet as if by a force-

Fig. 214.—Crater of Demavend.



pump, and the whistling of the water pent up between the rocks reminds one of the furnace of a manufactory at full work. One might fancy that it was the respiration of some prodigious being hid under the mountain.

The hottest springs which gush out on the surface of the ground, such as those of Las Trincheras and Comangillas, do not reach the temperature of 212° (Fahr.); but we have no right to conclude from this that the water in the interior of the earth does not rise to a much more considerable heat. It is, on the contrary, certain that water descending into the deepest fissures of the earth, although still maintaining a liquid state, may reach, independently of any volcanic action, a temperature of several hundred degrees; being compressed by the liquid mass above it, it is not converted into steam. At a depth which is not certainly known, but which various *savants* have approximately fixed at 49,000 feet, water of a temperature exceeding 750° (Fahr.) ultimately attains elasticity sufficient to overcome the formidable weight of 1,500 atmospheres which presses on it; it changes into steam, and in this new form mounts to the surface of the earth through the fissures of the rocks. Even if this steam, passing through beds of a gradually decreasing temper-

ature, is again condensed and runs back again in the form of water, still it heats the liquid which surrounds it, and increases its elasticity; it consequently assists the generation of fresh jets of steam, which likewise rise towards the upper regions. Thus, step by step, water is converted into steam up to the very surface of the earth, and springs out from fissures in the shape of *fumerolles*.

In Iceland, California, New Zealand, and several other volcanic regions of the world, jets of steam mingled with boiling water are so considerable as to rank among the most astonishing phenomena of the planet. The most celebrated, and certainly the most beautiful, of all these springs is the Great Geyser of Iceland. Seen from afar, light vapours, creeping over the low plain at the foot of the mountain of Blafell, point out the situation of the jet of water and of the neighbouring springs. The basin of siliceous stone which the Geyser itself has formed during the lapse of centuries is no less than 52 feet in width, and serves as the outer enclosure of a funnel-shaped cavity, 75 feet deep, from the bottom of which rise the water and steam. A thin liquid sheet flows over the edges of the basin, and descends in little cascades over the outer slope. The cold air lowers the temperature of the water on the surface, but the heat increases more and more in all the layers beneath; every here and there bubbles are formed at the bottom of the water, and burst when they emerge into the air. Soon bodies of steam rise in clouds in the green and transparent water, but, meeting the colder masses on the surface, they again condense. Ultimately they make their way into the basin, and cause the water to bubble up; steam rises in different places from the liquid sheet, and the temperature of the whole basin reaches the boiling-point; the surface swells up in foamy heaps, and the ground trembles and roars with a stifled sound. The caldron constantly gives vent to clouds of vapour, which sometimes gather round the basin, and sometimes are cleared away by the wind. At intervals, a few moments of silence succeed to the noise of the steam. Suddenly the resistance is overcome, the enormous jet leaps out with a crash, and, like a pillar of glittering marble, shoots up more than 100 feet in the air. A second and then a third jet rapidly follow; but the magnificent spectacle lasts but for a few moments. The steam blows away; the water, now cooled, falls in and round the basin; and for hours, or even days, a fresh eruption may be waited for in vain. Leaning over the edge of the hole, whence such a storm of foam and water has just issued, and looking at the blue, transparent, and scarcely-rippled surface, one can hardly believe, says Bunsen, in the sudden change which has taken place.

About the centre of the northern island of New Zealand the activity of the volcanic springs is manifested still more remarkably even than in Iceland. On the slightly-winding line of fissure which extends from the south-west to the north-east, between the ever-active volcano of Tongariro and the smoking Island of Whakari, in Plenty Bay, thermal springs, mud-fountains, and geysers rise in more than a thousand places, and in some spots combine to form considerable lakes. In some localities the hot vapours make their escape from the sides of the mountains in such abundance that the soil is reduced to a soft state over vast surfaces, and flows down slowly to the plains in long beds of mud. For a distance of more than a mile a portion of the Lake of Taupo boils and smokes as if it was heated by a subterranean fire, and the temperature of its water reaches on the average to 100° (Fahr.). Further to the north, the two sides of the valley, through which flows the impetuous river Waikato after its issue from the Lake Taupo, present, for more than a mile, so large a number of water-jets, that in one spot as many as seventy-six are counted. These geysers, which rise to various heights, play alternately, as

if obeying a kind of rhythm in their successive appearances and disappearances. Whilst one springs out of the ground, falling back into its basin in a graceful curve bent by the wind, another ceases to jet out. In one spot a whole series of *jets d'eau* suddenly become quiet, and the basins of still water emit nothing but a thin mist of vapour. Farther on, however, the mountain is all activity; liquid columns all at once shine in the sun, and white cascades fall from terrace to terrace

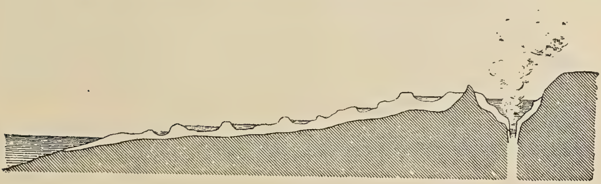
Fig. 215.—Volcanic Region of New Zealand.

towards the river. Every moment the features of the landscape are being modified, and fresh voices take a part in the marvellous concert of the gushing springs.

Nearly midway between Lake Taupo and the coast of Plenty Bay several other volcanic pools are dotted about, all most remarkable for their thermal and jetting springs. One of them, however, is among the great wonders of the world. This is Lake Rotomahana, a small basin of about 120 acres, the temperature of which,

being raised by all the hot springs which feed it, is about 78° (Fahr.). Dr. von Hochstetter has not even attempted to count the basins, the funnels, and the fissures from which the water, steam-mud, and sulphurous gases make their escape. Here and there, indeed, he noticed, altogether, *salses, solfataras, fumerolles,* and springs. The most magnificent of all these jets is the Tetarata, about 82 feet above the eastern bank of the lake. The basin, from the centre of which the water and steam spout out, is a kind of crater, 286 feet in circumference, which is surrounded by ramparts of red clay 32 feet in height, resembling the sides of a crater. The basin is full of clear water, which has entirely covered the former with a coating of silex, white as marble. The water in this dazzling basin assumes a delicious blue shade, which is rendered more beautiful by the reflection of the steam unrolling its spiral clouds. The liquid which flows from the basin runs into another pool, likewise covered by a coating of silex, and, falling from terrace to terrace, thus reaches the level of the lake. These glittering steps, over which the water spreads in thin sheets, and then falls in cascades, form a wonderful spectacle of splendour and grace. Sometimes—say the natives—the whole body of liquid in the upper basin is suddenly upheaved in an enormous column, and the pool empties

Fig. 216.—Section across the terraced Basins of Tetarata.



30 feet of its depth ; in this case nothing can be wanting to complete the grandeur of the picture.

Have these wonderful springs existed for any great length of time, and are they destined to be preserved for centuries in all their beauty ? These are points as yet unknown. When the New Zealand springs have been studied for a considerable number of years, it will perhaps be possible to describe the various modifications which are taking place in consequence of the increase or relaxation of the subterranean action in these regions. In several parts of Europe thermal springs have gradually lost both their heat and their mineral qualities, owing to the cooling of the furnace which heated them, and are becoming more and more similar to ordinary springs : of this kind, for example, are the springs of Bertrichbad, in Luxembourg.

Of late years the American geologists Doanly, Langford, and Hayden have discovered on the Wyoming and Montana plateaux, where rise the Rivers Madison, Yellow-stone, and Snake, multitudes of thermal springs and geysers, which are unquestionably the grandest phenomena of this sort in the whole world. One of the jets, over 200 feet high, is capped by a cloud of vapour rising to a height of 1,000 feet. The Beehive, another of these fountains, is 220 feet high ; and thick columns of water ejected by the Giant is encircled by others attaining the prodigious elevation of 240 feet. The banks of the River Firehole are everywhere lined with craters, some still active, some quiescent, with flooded or empty basins, siliceous concretions, mud volcanoes, liquid columns of diverse coloured waters

occasionally mixed with a kind of mortar or blackish mud. Most of the springs are independent of each other, standing at different levels, with different action and temperature. So surprising are all these natural marvels that in 1872 Congress was induced to reserve the whole region, 3,700 square miles in extent, as a national park, so that the beauties of this stupendous landscape may never be marred by the vulgar works of modern builders.

The gases which make their escape from the *fumerolles* situated above hidden beds of lava do not differ from those produced by great volcanic eruptions; they are the hydrochloric, sulphuric, and carbonic acids, either in a state of purity or in combination with alkaline, earthy, or metallic bases, and, as in the moving currents of lava, they indicate by their composition the degree of intensity of the subterranean heat. The most precise indications on these points have been furnished by the analyses of MM. Bunsen, Ch. Sainte-Claire Deville, and Fouqué.

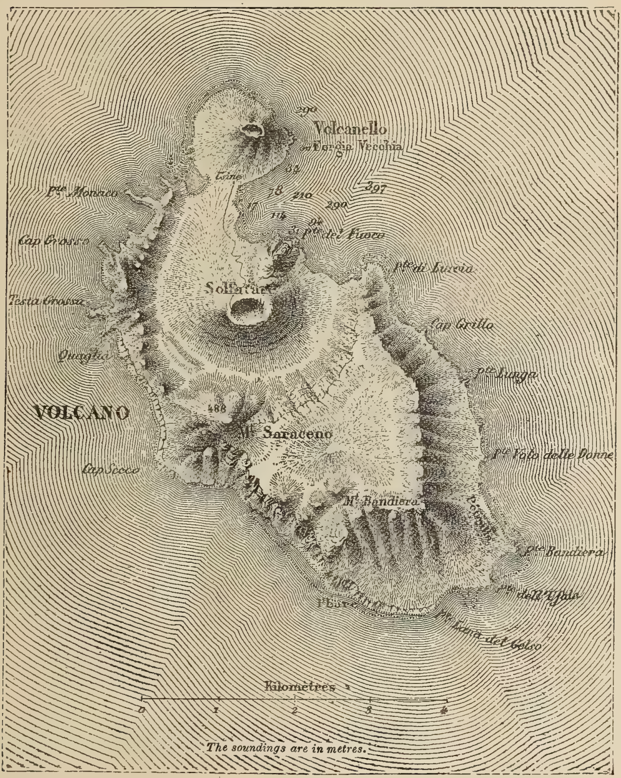
When they issue from the earth, *fumerolles* deposit on the edges of the fissure various substances, such as sulphur, alum, and borax, which have been sublimated in the subterranean laboratory; the vapours then spread out into wide eddies, and are lost in the air. There is no spot in Europe where these *fumerolles* can be better studied than in the former crater of the Isle of Volcano. The cavity, at the bottom of which all these chemical operations take place, is more than a mile in circumference, and its southern sides rise to 980 feet in height; the bottom of the abyss may be about 320 feet wide. Through the mist of vapour which fills the immense caldron a spectator sees the lofty cliffs, red or golden yellow in colour, and streaked here and there with most varied hues. On the slopes leading to the bottom of the gulf the crumbling stones give way under the tread, and yet it is necessary to descend at a running pace, for in some places the hollow soil is burning like the arch over an oven. Vapour creeps along slowly over the slopes. The air is saturated with hydrochloric and sulphurous acid gases, and is difficult to breathe. An incessant noise of dull sobbings and whistlings fills the hollow, and on every side there are small orifices between the stones, whence jets of steam spring eddying out. This is the spot whither the workmen—who seem accustomed to live in the fire, like the legendary salamanders—resort to gather the stalactites of gilded sulphur which still crackle from the effect of heat, and the fine needles of boracic acid, white as swan's-down. At night the masses of vapour accumulated above the crater are coloured with a red glare, as if from the reflection of an immense fire.

Sometimes the rain which falls into the amphitheatre forms there a temporary lake; but a great part of the water makes its escape through the fissures in the ground, and flows in a stream over the external slopes, the remainder being evaporated by the heat of the mountain. Some of the *fumerolles,* the gases of which were analysed in 1865 by M. Fouqué, attain a temperature above 680° (Fahr.). Other jets of less heat make their appearance in various parts of the island, and even in the waters of the bay. From the edges of the great crater these vapours may be seen at the base of the slopes rising from the bed of the sea, and developing into wide, whitish-coloured spirals, similar in hue to the mud of potters' clay. In certain places the temperature of the sea-water heated by these gases is so high that voyagers can afford themselves the childish satisfaction of boiling their eggs in it.

The *solfatara* in the Isle of Volcano produces scarcely ten tons of sulphur every year. This does not seem much; but if we were to calculate by centuries and geological periods the quantities deposited by the *fumerolles,* it would seem really enormous. Thus, the mines of Sicily, which have been worked for some centuries,

furnish every year to commerce no less than 300,000 tons of sulphur; and yet the mining operations in these districts are altogether of a primitive character. A large number of beds are unexplored, and nearly a third of the sulphur brought

Fig. 217.—Island of Volcano.



to the surface evaporates in the furnaces or is lost in the *débris*. These almost inexhaustible veins appear to have been all produced, like the deposits of the Isle of Volcano, by jets of vapour saturated with sulphur.

CHAPTER LXXI.

SUBMARINE VOLCANOES.

THE bed of the sea is, of course, inaccessible to our observation, but still there can be no doubt that the phenomena of submarine volcanoes resemble those of the burning mountains which tower so high above the ocean. Whenever the crest of an isle of scoriæ rises above the waves, all that we see of its eruptions suffices to prove that they take place exactly in the same way as those of the volcanoes on the mainland. There exist, however, in several places, former submarine craters, which, since the period of activity, have been upheaved, with the plains surrounding them. The history of these craters, written legibly in their strata, is just the same as that of other volcanic outlets. Still, as would necessarily be looked for, on account of the pressure exercised by the immense body of sea-water, the cones of *débris* which have been formed under the pressure of the waves are, without any exception, more flattened than mountains of the same nature which have taken their rise on *terra firma*. With regard to the lava which issues from submarine fissures, it sooner becomes solidified, and does not flow to such great distances. Often, also, it is converted, under the superincumbent weight of the water, into basaltic colonnades. We can also readily understand that the vapour must rapidly condense while passing through the mass of cold water. It is only when the mouth of the crater is very close to the surface of the ocean that columns of vapour are freely discharged and ascend into the air.

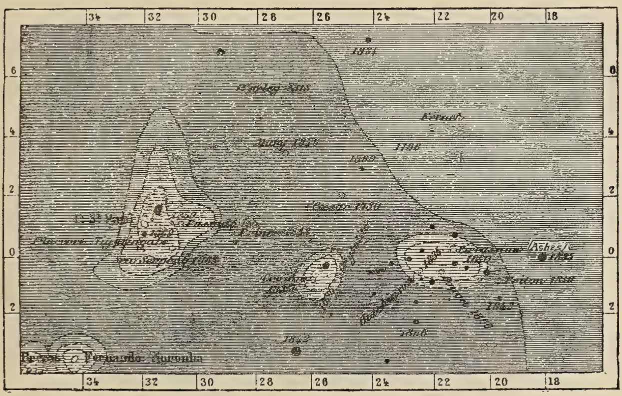
Most submarine eruptions which have been known in modern times have taken place at no great distance from some of the great insular or continental volcanoes. The Sicilian Sea, the Greek Archipelago, the waters near St. Michael in the Azores, the portion of the Caspian which surrounds the Peninsula of Apsheron, the seas of Japan and of the Aleutian Isles, the Gulf of Darien, and the coast of Iceland, form, probably, a part of the same subterranean regions of activity as the volcanoes situated on the adjacent shores. There is, however, one volcanic district which is exclusively submarine; this is the narrowest part of the Atlantic, embraced between the two extreme points of the coasts of Guinea and Brazil. In this tract of the ocean the water is often agitated by violent shocks, and ships tremble as if they had run upon a sand-bank. Smoke, as if from a conflagration, rises above the waves, and pumice-stone and other light scoriæ are floated about by the current. Even islands of ashes have been noticed to emerge from the midst of the sea, which, being washed away by the waves, have diminished, and ultimately disappeared. Barry has prepared a chart of this equatorial region of the Atlantic, showing all the places known to have been the scene of submarine eruptions, seaquakes, or other

oceanic disturbances. In the Mediterranean also volcanic eruptions have been recorded in deep water. On February 23rd, 1876, the screw steamer *Knight Templar,* when in the neighbourhood of Galita, where the chart indicates a depth of nearly 6,600 feet, felt a sudden and violent shock as if it had struck a reef. A leak was sprung which it afterwards appeared was caused by a stone from some submarine volcano striking the keel and carrying off a strip over 10 feet long.

The submarine cones proceeding from the bottom of the sea which resist the action of the water are those which have their layers composed of lava. The group of Aleutian Isles contain at least two mountains which have emerged from the water within a recent period. According to the accounts of the Chinese and Japanese chroniclers, several volcanoes have risen from the bed of the sea on the coasts of Japan and the Corea during the historical period. In the year 1007 a

Fig. 218.—Volcanic Region of the Equatorial Atlantic.

Scale 1 : 22,400,000.



Earthquakes. Violent Shocks.

The dates indicate the year of the event.

0 to 1,000 Fathoms. 1,000 to 2,000 Fathoms. 2,000 to 3,000 Fathoms. 3,000 Fathoms and upwards.

0 150 300 450 Miles.

roar of thunder announced the appearance of the volcano of Toinmoura, or Tanlo, on the south of the Corea, and then, after seven days and seven nights of profound darkness, the mountain was seen; it was no less than four leagues in circumference, and towered up like a block of sulphur to a height of more than 1,000 feet. More than this, the celebrated Fusi-Yama itself, the highest mountain in Japan, is said to have been upheaved in a single night (?) from the bosom of the sea twenty-one and a half centuries ago. With respect to marine volcanoes of a more recent epoch, we may mention all the isles of either extinct or still burning lava which rise in pyramids like Stromboli, or extend in a graceful semicircle like the crater of St. Paul in the Indian Ocean. Lakes also exhibit a number of volcanoes of the same kind. Such are Momotombo of Nicaragua, and the Taal of the Lake of Bongbong, in the Island of Luzon.

The sudden appearance of lava which has most impressed the popular imagination for many years past, and has also been best studied by scientific men, is the formation of hillocks of lava in the Santorin group. This circular archipelago is doubtless the remains of a great cone, 30 miles in circumferenee, which once rose in the midst of the sea. In consequence of the action of the waves, earthquakes, and subsidences, the sides of this cone were broken in upon and finally ruptured by the water. When the Hellenes established themselves in the islands of the Ægean Sea, the shattered mountain was divided into three fragments: one fragment assuming the form of a crescent, and comprehending the larger portion of the former volcano, constitutes the Island of Thera, or Santorin; on the west, the

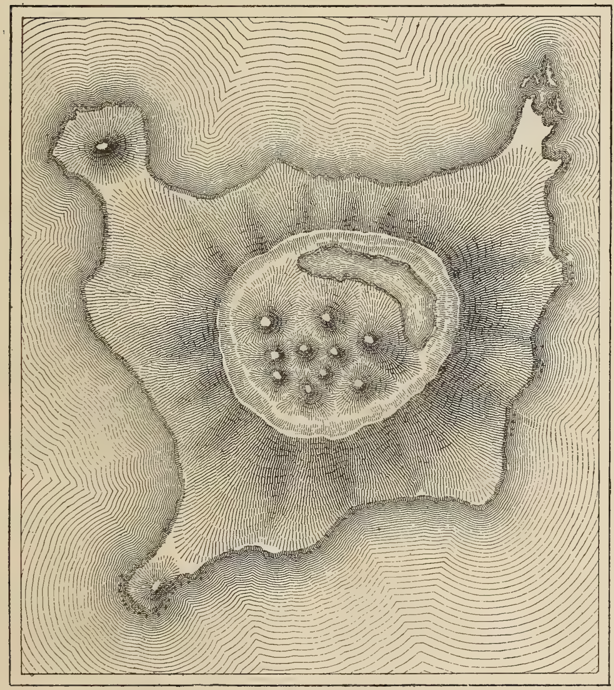
Fig. 219.—Isle of St. Paul: the Measurements are in Metres.

little Isle of Therasia bends round in continuation of the ring of land; and, on the south-west, a great rock, the Islet of Aspro, rises as if to bear witness to the rampart of lava now disappeared. The outer slopes of Santorin and Therasia, partially covered with pumice-stone somewhat resembling a coating of snow, are rather gently inclined towards the sea, but the escarpments, turned in the direction of the basin, which was once the crater, are in some places nearly perpendicular for a height of 650 and even 1,300 feet. The various layers, which correspond on the two sides of the gulf—on the sides of Therasia and of Santorin—are vividly marked out in bands of a red, yellow, blue, black, or white colour.

In the centre of this crater, after a series of upheavals and eruptions, an islet of

lava emerged about the year 196 B.C. It was named Hiera (Holy), and on the summit a temple to Neptune was built. This islet, which was several times increased in the centuries which followed—in the years 46, 713, 726, and 1427 A.D.—is now known under the name of Palæo-Kaïmeni. Not far from this isle, another smaller one, Mikro-Kaïmeni, rose in 1570 or 1573. At the commencement of the eighteenth century, from 1707 to 1711, another mass of lava, Neo-Kaïmeni, an island no less than four miles in circumference, emerged within the annular crater formed by the crescent-shaped Santorin and the Isle of Therasia. In 1768 Neo-Kaïmeni was shaken by a violent eruption. From this date to 1866 no visible

Fig. 220.—Volcano of Taal.



change took place above the water, but soundings proved that the bed of the sea had gradually risen. At a point near Mikro-Kaïmeni, a bank of rocks, situated in 1794 at a depth of 80 to 100 feet, was in 1835 only 13 feet from the surface. "Such is the singular fecundity of Santorin," says an historian of this volcano, "that isles seem to grow up round it like fungi in a wood."

At the end of January, 1866, subterranean roarings, a gradual sinking of the ground, and the colouring of the water, announced an approaching eruption. The centre of the shock was felt just below the little village of Vulcano situated on the edge of a creek where ships used to cast anchor in order that the water, mingled as

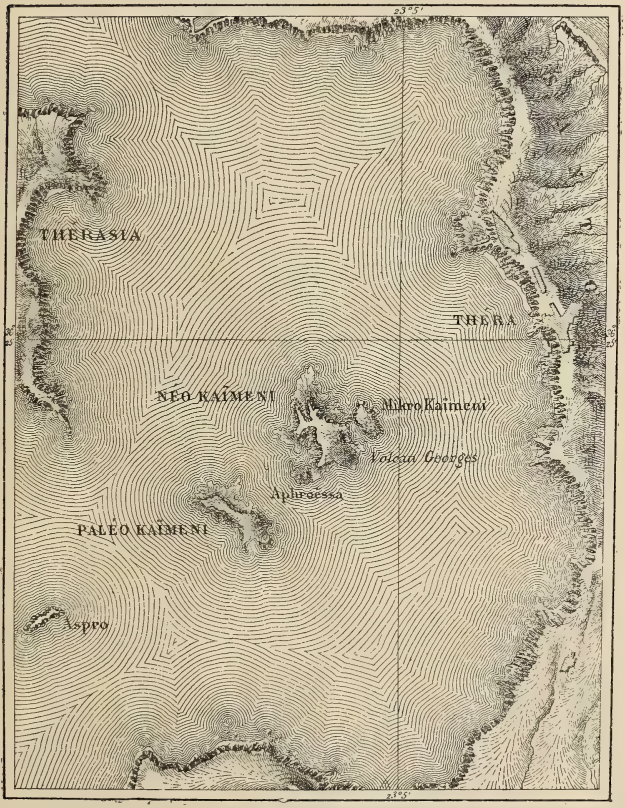
it was with acid gases, might destroy the molluscs and seaweed attached to their keels. On the 3rd of February a brilliantly black mass of lava was seen, which rose slowly from the bottom of the water, and increased in size every day with perfect regularity. This mound, designated by the name of George's Isle, attained in a few weeks a height of 164 feet, and ultimately became united to Neo-Kaïmeni, having filled up the creek of Vulcano. On the 7th of February, another mound, the Isle of Aphroessa, rose at a little distance to the south, and gradually filling up the channel which separated it from Neo-Kaïmeni, became converted into a promontory. Afterwards other islets made their appearance by the side of the

Fig. 221.—Santorin.

two principal cones. All round them the sea, agitated by the gases which rose in great bubbles, exhibited in turn the most diversified hues. It was in succession reddish-coloured, milk-white, or shaded with green or a chemical blue; it was, besides, generally tepid or hot. The fish, either asphyxiated or killed by the heat, floated in multitudes on the surface, and mariners avoided steering their ships anywhere near the eruption, for fear the pitch between their planks should melt in the water heated to a temperature of 160° to 170° (Fahr.). The summit of the crater of Neo-Kaïmeni was shaken by frequent explosions. On the 20th of February lumps weighing 220 pounds were suddenly darted out to a distance of several hundred yards, showers of ashes fell upon the vines of Santorin, and clouds

of *débris*, making their escape from the crater, shot up to a height of 6,500 to 6,800 feet. It was not before the end of the year 1866 that the cone of George's Island opened out for itself a crater by an explosion which destroyed the whole of the upper portion of the mound. But the intensity of the eruptive phenomena soon after gradually diminished. Currents of lava more than half a mile long were in some places more than 300 feet in depth. It is evident that the reason why the molten matter has thus formed in heaps close to the outlet, instead of flowing in

Fig. 222.—Kaïmeni Group.



long streams, as on the sides of Vesuvius and Etna, is that the lava, soon becoming cool by its contact with the salt water, was necessarily compelled to arrest its progress.

In the month of February, 1877, the Sandwich Islands were the scene of submarine disturbances all the more remarkable that they were accompanied by convulsions on the mainland of Hawaii. Above the crater of Mauna-loa (16,000 feet) dense vapours rose to a height of 32,000 feet, spreading over an aerial space of

120 square miles. Then the land was suddenly rent, leaving a crevasse from a few inches to over three feet wide which was continued far seawards. At the lower extremity of this fissure, near the entrance of Kealakeakua Bay, over a mile from the coast, a stream of lavas was ejected, and the surface of the sea became covered with a vast quantity of pumice and scoriæ, which when saturated with water gradually sank to the bottom.

The cones of shifting ashes which are thrown out by the eruptions of submarine volcanoes are not able to resist the action of the waves for any length of time; and however great may be their dimensions, they are certain ultimately to disappear, unless they are based on solid foundations which have entirely emerged from the water. As an example of this we may mention the celebrated Julia or Graham's Island, which appeared in July, 1831, throwing up heaps of dark-coloured scoriæ about 25 miles south of the shores of Selimonte, in Sicily. An English captain, proud of being able to increase the British domains, hurried to hoist his flag over the smoking stones. The islet gradually increased round the crater, and before long it measured as much as four miles round. But, at the conclusion of the

Fig. 223.—Graham's Island, or Isle of Julia.

volcanic eruption, the work of demolition commenced, and, in conformity with M. Constant Prévost's prediction, the slope of *débris* was gradually undermined at the base by the waves and currents. In October nothing remained but a little mound. Six months after, the newly-discovered island, which was also claimed by the King of Naples through his diplomatists, was nothing more than an oval reef about half a mile long. A few years later the sounding-line showed a depth of 787 feet. In July, 1863, the isle again appeared, and, in a few weeks, rose to the height of 200 to 260 feet; but it existed only for a short space of time, for it soon again sank, being demolished stone by stone by the dash of the waves. It appears, however, that, previously to 1831, the volcano had made its appearance on one or two other occasions. It is said that a smoking island existed in this spot about the year 1801, and the shoal is pointed out in old charts. This island, first rising up above the waves and then sinking down again into the depths of the sea, seems to recall the recollection of that mysterious country mentioned in the "Arabian Nights," which plunged down into the ocean just at the moment when the voyagers were going to land on it.

CHAPTER LXXII.

EARTHQUAKES.—VIBRATIONS OF THE GROUND.—VARIOUS HYPOTHESES.

AS volcanic eruptions sufficiently show, this planet is not the immovable mass which our imaginations depict it, when comparing it to the atmosphere which surrounds it, to the ever-mobile waves of the ocean, or even to the animated beings which wander over its surface. On the contrary, the ground which we tread under our feet vibrates very frequently. Without alluding to those great shocks which overthrow cities, bring down the sides of mountains, and open vast cracks across plains, there are other less violent vibrations, which have been recorded by the annalists of geological history, and may be reckoned by thousands as regards civilized countries and modern times alone. There can be, however, no doubt that the great majority of slight earthquakes pass unnoticed, being blended, especially in towns, with the confused rumbling of noises and murmurs. Various *seismological* instruments, recently invented or brought to perfection, reveal a large number of oscillations which it would be impossible to discover in any other way. An attentive observation of the levels of air-bubbles and of micrometrical threads reflected on the surface of a bath of mercury has, indeed, warranted M. d'Abbadie in asserting, in 1837, that the earth is in a state of constant vibration. The intervals of immobility which he has noted have never exceeded thirty hours.

What is the cause of these trepidations of the ground? A great number of *savants*, who have accepted the hypothesis of a *pyriphlegeton*, or central fire, do not hesitate to look upon these vibrations of the earth as the repercussion of the undulations of the great burning sea. Each of the shocks which are felt on the surface of the earth would then take its rise below the envelope of the planet, and would be at first produced in the form of a current or tide in the burning mass which is supposed to exist. As Humboldt says, an earthquake would be "the reaction of the liquid nucleus against the outer crust." Added to this, most geologists who base their arguments on the hypothesis of a central fire, admit that earthquakes must necessarily be in connection with volcanic phenomena, and that they invariably proceed from the same cause. Following out the comparison which must always present itself to the mind, the mouths of volcanoes are saftey-valves, and, on account of the obstruction of these outlets, the pent-up lava or vapour shakes the superincumbent layers of the terrestrial envelope, seeking to find some way of issue. This theory has the merit of being very simple, and, in a large number of cases, seems to harmonize very satisfactorily with the facts that have been observed. But we must never forget that, however probable this hypothesis as to the volcanic action may be, it is at variance with many known facts; and the

duty for the geographer still is to study events impartially, and to suspend his judgment until a satisfactory conclusion evidently results from the whole body of facts observed.

In the first place, it is important to know if those regions on the surface of the globe in which earthquakes take place with the greatest frequency are distinguished from other parts by any peculiar features in the form of their vertical outline, or in the nature of their rocks. The volcanic districts in Europe, such as the environs of Vesuvius and Etna, the Islands of Santorin and Milo, and the south of Iceland, are not the only places which are subject to severe shocks; the former districts, too, have never been so violently agitated as the mountains of the Abruzzi and Calabria, the Islands of Rhodes and Cyprus, the limestone districts of Carniola and Istria, the Alps of the Valais, the environs of Basle, certain plateaux in Spain, and the hills at the mouth of the Tagus. The mountains of Scotland, and especially those in the county of Perth, have also experienced repeated shocks: out of two hundred and twenty-five earthquakes recorded in the British Isles, eighty-five have taken place in this one county. In Africa, the soil of Algeria, so rich in saline and thermal springs, but devoid of volcanic craters, is sometimes very severely shaken. The districts of the Nile, which are likewise without volcanoes, have also suffered much from subterranean movements. In Asia, the peninsula of Guzerat, a spot in which astonishing modifications of the shape of the coasts were produced during a great earthquake, is situated more than 1,240 miles from the nearest volcanoes, the Demavend and the burning mountains of Thian-Shan; but, on the other hand, the Philippines and Japan, which are volcanic countries, are also frequently agitated by movements of the ground. Again, the sea-coast of Syria, the towns of Aleppo and Antioch, the scenes of some of the most destructive earthquakes that are recorded in history, no longer possess very active volcanoes, and the lavas of the Jebel-Hauran, on the south-east, have long been extinct. In South America most of the great shocks have taken place in the region of the Andes, or not far from their bases. The Argentine town of Mendoza, which was overturned in the violent earthquake of 1861, is comparatively not far from a lava-furnace, since the volcano of Maypu rises at a distance of only 87 miles. The Equatorial Andes are often convulsed by violent oscillations of the soil, and are also the theatre of great volcanic activity, many of their summits being domes of trachyte or craters still vomiting out ashes, mud, or smoke. Nevertheless, according to the testimony of Boussingault, the most energetic shocks experienced in Columbia—those which destroyed the towns of Latacunga, Riobamba, Honda, Merida, and Barquesimeto, and were simultaneously felt over a very extended area—presented no coincidence whatever with any volcanic phenomena, and their centre of agitation was situated at a considerable distance from the smoking peaks. The plateau of Caraccas, celebrated for the catastrophe of 1812, is situated more than 600 miles eastward of the Grenadini volcanoes of Huila and Tolima, and at rather a less distance from the craters of the Antilles, from which it is separated by wide arms of the sea. Finally, the region in North America where oscillations of the ground are most frequent and most severe is the alluvial plain of the Mississippi, far distant from any volcanic district, and even from any great chain of mountains. Thus, although the history of earthquakes is known only for a few centuries, and over but a small portion of the earth's surface, it is certain that severe oscillations of the ground are felt in countries the most diverse, which bear no resemblance to one another, either in their formation or their aspect. The only fact which seems well established is, that shocks are more frequent in mountainous than in flat countries. Nevertheless,

if, as Mr. Mallet thinks, all earthquakes not followed by an eruption are "incomplete efforts to open a volcano," if they are produced by the endeavours made by the planet to get rid either of gas or the molten matter within, the ground ought to be most frequently agitated in continental plains, far from volcanoes and mountains; for in those localities there would be no natural "vent-holes" through which to discharge the overflow of the interior fluids, and there, too, according to the common theory, the terrestrial layers must be the thinnest.

There are a certain number of cases in which, independently of any theory, we can without difficulty substantiate a relation of cause and effect between a volcanic eruption and an earthquake. Thus, when the sides of a smoking mountain, such as Etna or Kilauea, are suddenly cleft asunder to pour forth a stream of lava, and at the same time the ground is strongly agitated, it is evident that the earthquake is caused by the fracture of the volcano. This local phenomenon is precisely analogous to that produced by the explosion of a mine or a powder-mill. When the fissure is of a considerable length and the fractured sides of the volcano present a great thickness, the shock is a violent one, and reverberates in long oscillations in all the adjacent districts. When, on the contrary, the rocks of the volcano, having been diminished in thickness and partially melted by the rising lava, yield more easily to the pressure which bursts them, the explosion is only felt in the immediate vicinity of the fissure. Thus, at the time of the last great eruption of Etna, the trepidations of the ground, which coincided with the formation of the fissure, were in general very slight, and the sharpest of them, which was, however, perceptible in the town of Aci Reale, was not felt beyond the Etnean region properly so called. History also affords several examples of volcanic eruptions during which the ground was not perceptibly shaken. In May, 1855, Vesuvius vomited out a considerable quantity of lava without the least trace of any motion of the ground being perceived either in the observatory on the volcano or at Naples.

When the ground of a volcanic region is convulsed by shocks, and we are unable to observe the least connection, either as regards coincidence or immediate succession, between these phenomena and the eruption of a cone of ashes or the emission of a current of lava, we evidently have no scientific reason for asserting, with any certainty, that these shocks originate in the subterranean furnace of burning matter, or that they are caused by vapour endeavouring to break through the terrestrial crust. For still stronger reasons, a similar assertion would be contrary to all the rules of scientific observation when applied to earthquakes which take place far from any volcano. Certainly, according to the "safety-valve" hypothesis, oscillations of the ground ought to take place just in those very localities of the planetary envelope in which there exists no orifice communicating with the lava. But how is it, then, that undulations of the soil are not constantly produced at places far from these gigantic vent-holes situated on the sea-coast? And how does it happen that frequent eruptions of Vesuvius and Etna do not precede the Calabrian earthquakes, and afford an issue to the pent-up vapour and lava?

The hypothesis that volcanic forces are the cause of earthquakes, being one that cannot be justified in every case, we must have recourse, in respect to many of these phenomena, to some other theory—one, in fact, which in all time has suggested itself to the minds of various people, and was taught by the Greek philosophers. Some two thousand years ago, Lucretius propounded this idea in magnificent language—an idea which has now been scientifically adopted by Boussingault, Virlet, Otto Volger, and other geologists.

"Learn, now, the cause of earthquakes, and first be assured that the interior of

the globe is, like the surface, filled with winds, caverns, lakes, precipices, stones, rocks, and a large number of rivers, the impetuous waves of which hurry along in their course numerous submerged blocks. The shakings of the surface of the globe are occasioned by the falling in of enormous caverns which time has succeeded in destroying. Whole mountains thus sink in ruin, and the violent and sudden shock is spread far and wide in terrible vibrations. Thus a chariot, the weight of which is not, however, very considerable, makes all the houses near tremble as it passes, and the fiery steeds, drawing behind them the iron-armed wheels, shake all the places round. It might well happen that an enormous mass of earth should fall by reason of decay into some great subterranean lake, and that the globe should tremble in a series of undulations. In like manner, on the surface of the earth, a vessel filled with liquid in a state of agitation cannot resume its equilibrium until the water contained in it has found its level."

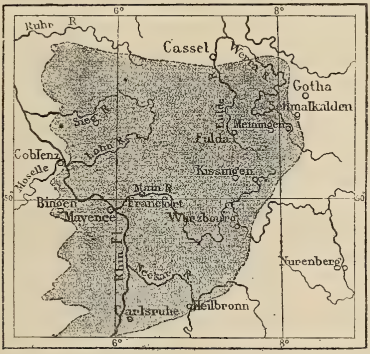
Various *savants* have recently collected a large number of facts which are in favour of the theory of earthquakes once propounded by Lucretius, although only generally and without the necessary proofs. In a vast number of cases this theory is certainly the true one, for it is often possible to catch in the act, so to speak, the phenomena which give rise to the oscillations of the ground and the subterranean thunders. Thus great landslips, such as those of the Diablerets, Rossberg, and other mountains of the Alps, have caused real earthquakes, the waves of which were felt at a considerable distance from the scene of the catastrophe. Even the falls of *moraines, séracs,* and avalanches of snow shake the ground very severely over considerable areas, so much so that in the mountains of Allemont, in Dauphiny, the inhabitants consider all the vibrations of the ground as the reverberations of distant downfalls of snow or rocks.

The subsidence of rocks or shifting soil is accompanied by similar phenomena. In September, 1814, near Alaix, for twenty-four hours a series of detonations were heard like a cannonade, and then, after a formidable cracking noise, the ground sank 13 feet for a breadth of more than 88 yards. Not far from the town of Wagstadt, in Silesia, in 1827, a tract of more than two acres in area sank in a similar way with a great crash. In Carniola, where earthquakes are not unfrequent, heaps of fallen rocks are noticed in the numerous caverns, which heaps correspond with the funnel-shaped cavities on the surface of the ground. These subsidences, which man sometimes personally witnesses, either in districts hollowed out by natural caves, or in mining regions pierced with subterranean galleries, may cause local shocks, or, in proportion to the mass of rocks falling, give rise to earthquakes felt simultaneously over vast extents of country. In fact, certain rocky strata sometimes leave intervals between them of very considerable depth, as may easily be noticed on the sides of mountains, and they may, besides, be composed of substances which are more or less easily dissolved and washed away by the infiltrated water. When these voids extend so far that the rocks above, sometimes hundreds or even thousands of yards in thickness, can no longer maintain their position by means of their own cohesion, the whole mass must necessarily fall down on the beds beneath. It is, indeed, impossible to imagine that it can be otherwise; the enormous quantities of salt, gypsum, lime, silex, and other substances which springs bring up to the surface must of necessity leave great voids in the depths below, and, in consequence, the subsidence of the rocks above these vacant spaces becomes inevitable. Only imagine, if it is possible, the potency of the shock produced by the sudden fall of several millions of cubic yards.

Earthquakes produced by artificial causes in no way differ from natural shocks

in the effects which they produce; they, indeed, furnish us with excellent terms of comparison. The explosions of mines and the passage of heavily-laden trains cause a motion of the ground over areas increasing in extent as the initial pressure is more considerable, and as the rocks present a greater degree of elasticity. Cannonades, the reaction of which on the earth is, however, trifling in proportion to the effect produced, are heard at distances which seem prodigious, if the ear is applied to the surface of the agitated ground. Vibrations of the layers of the earth —in fact, real earthquakes—are thus prolonged for more than 250, or, indeed, for 375 miles. Thus, in 1832, the bombardment of Antwerp was heard, it is said, in the Erzgebirge, in the centre of Germany. Twenty-five years ago, at the time of the explosion of the powder-mills of Mayence, a very large area of ground was made

Fig. 224.—Area over which was felt the Explosion of Gunpowder at Mayence.



to tremble. More than 10,000 lbs. weight of the gunpowder exploded (the greater part) blew up in open vaults, and could not, therefore, react on the ground; yet the shock was felt either as a slight trembling of the ground or as distant thunder as far as 100 to 125 miles away, far beyond the districts to which the sound of the detonation was carried by the wind. The shock was felt at several towns in Swabia, at Wurzburg, at Kissingen, in the countries of Fulda and Meiningen, in Thuringia, near Cassel, and at Wildungen. Doubtless the observations made on earthquakes in the various countries of the world, whether these phenomena are produced with or without the intervention of man, will some day enable us to estimate approximately the force that is necessary for shaking some given area of the earth's surface. These would be comparative studies which could be made without prejudice in favour of the hypothesis of the central fire or any other theory.

CHAPTER LXXIII.

GREAT CATASTROPHES.—EARTHQUAKE AT LISBON.—AREA OF DISTURBANCE.—EARTHQUAKES AT SEA.

THE sudden vibrations which overturn cities in a few seconds are the most frightful catastrophes that can be imagined by man. All other disasters are announced by some precursory signs. The stream issuing from the volcano advances but slowly, and its progress across villages and cultivated land may be foreseen. The floods of rivers threaten the embankments long before they break through them, and preparation may generally be made for the irruption of water. Even the hurricane is preceded by atmospheric signs; but earthquakes generally happen suddenly and unexpectedly, and in an instant, without a single sign to explain the catastrophe, whole cities are demolished, and the inhabitants destroyed by thousands. The earthquake of San Salvador only lasted ten seconds, and this space of time was sufficient for the destruction of the town. The successive vibrations which devastated Calabria, in 1783, were felt during barely two minutes. The terrible movements of the earth which destroyed Lisbon succeeded each other during the space of five minutes; but it was the first shock, lasting from five to six seconds, which caused the greatest damage. The inhabitants sometimes make use of the brief respite given them by the intervals between the great shocks, not in taking refuge in the open air, but in increasing still more their chances of death: struck with terror, they rush into the churches, the roofs of which fall in upon them. After some of these catastrophes the corpses may be counted by tens of thousands: the shocks in Sicily, in 1693, and Calabria, in 1783, must have caused in each of those two countries the death of 100,000 persons. Lastly, records of more or less credibility speak of earthquakes in Syria, Japan, and the Sunda Archipelago, which resulted in a sudden loss of life still more considerable. In 526 more than 200,000 people met their death at Antioch and the adjacent towns.

These undulations, which are so terrible in their consequences, are simultaneously felt over vast areas. Thus, the commotion which destroyed Lisbon on the 1st of November, 1755, and demolished the greater part of Oporto and several other places in Portugal, threw part of the walls of Cadiz into the moats, and it is said, on the testimony of the governor of Gibraltar, that the greater part of the towns of Morocco, Tetuan, Tangiers, Fez, Mequinez, and even the capital itself, were overthrown by the earthquake. Kant, the philosopher, and Hoffmann, who were the historians of the earthquake at Lisbon, mention a great number of other countries in Europe, Africa, and even the New World, which must have participated in the disturbance. The vibrations are said to have extended over an area of

15,400,000 square miles, or about a twelfth part of the terrestrial surface. But the statements upon which the various accounts of the catastrophe are founded are not always of any great value; it is now proved that the extent of the area over which the undulations of the earth were felt on this occasion has been singularly exaggerated. In the whole of Europe popular imagination was so struck by this event, which in the course of a few minutes, and, indeed, on a day of festival, destroyed so many thousands of persons under the ruins of a great capital, that it was naturally led to look upon the earthquake at Lisbon as a phenomenon without parallel, the scene of which was, if not the whole world, at least a great part of the terrestrial surface. All the oscillations which were felt in Europe, either on the same day or about the same time, were considered in a general way as the result of the great

Fig. 225.—Chart of the Earthquake of 14th September, 1866.

commotion at Lisbon; and gradually a sort of legend was established attributing to the same cause a considerable number of geological facts of an undecided date, such as the downfall of rocks, the formation of lakes, the breaking up of ice, and changes of temperature in thermal springs. Thus a shock which, "by a strange chance," was felt at Turin alone on the 9th of November, a week after the catastrophe at Lisbon, was attributed to this vast disturbance. The movements of the soil described as having taken place at New York on the 18th of November are also reckoned among the undulations which were then spread far and wide. The Lake Ontario was also added to the immense area of disturbance, because strong vibrations agitated its shores during the month of October; that is to say, before the day of the disaster. As a matter of fact, there is no positive proof that the terrestrial wave spread farther than Morocco on the south, the Castiles on the east, or in a

northerly direction farther than Angoulême and Cognac. This, however, constitutes an area of 1,118 miles in length, and if, as the diameter of the area of disturbance, the same distance is taken in the direction from east to west, we shall find that the area of the earth shaken by the great terrestrial wave of Lisbon was more than 1,158,000 square miles, or about six times the size of France. As a term of comparison, we will mention the earthquake which was felt in France on the morning of the 14th of September, 1866, the undulations of which were propagated to the north as far as Rouen, and to the south as far as Bordeaux, over an area of disturbance estimated at about 77,218 square miles.

At the time of this latter event there was one fact which contributed much to extend the apparent area of disturbance; this was, that a marine wave, harmonizing with the shock of the earth, was spread across the Atlantic in all directions. But the water being more easily moved than the soil, necessarily transmitted the wave to a greater distance than the comparatively rigid beds at the bottom of the sea. At the mouth of the Tagus the wall of water formed by the waves rose, it is said, to a height of nearly 56 feet; then, filling up all the estuary that extends in front of Lisbon, swept over the quays of the city, and rushed among the houses. At Cadiz a wave of nearly equal size rose above the ramparts, and caused much more havoc than the earthquake itself. On the coasts of Madeira and of Holland, the mouth of the Elbe, the sea-shores of Denmark and Norway, and, lastly, the whole circumference of the British Isles, the sea felt the reaction of the shock communicated to the waves in the waters off Lisbon, and its level underwent rapid fluctuations. The undulations of the wave, variously modified by currents and tides, struck even upon the shores of the New World. At Barbadoes and Martinique, where the flow of the tide never exceeds 28 inches, the wave produced by the Transatlantic earthquake attained a height of 13, 16, and even 19 feet. Thus the marine wave was carried to a distance of 3,728 miles in a straight line.

When violent shocks agitate the ground, towns situated on the sea-shore have often suffered much more from the sudden irruption of the water than from the shaking of the earth itself. When the waves receive the shock from the neighbouring coasts, or else when the centre of disturbance is at the bottom of the ocean, the masses of water rise to a formidable height, and dash upon the shores, as if during a hurricane. In 1783, at the time when the shock in Calabria overthrew the towns and villages on the mainland, a terrible bore, after having swept away at once 2,000 persons assembled on the coast of Scylla, rushed into the port of Messina, sank all the ships, and undermined the base of the superb rows of palaces which bordered the shore: more than 12,000 individuals perished, it is said, under the ruins. On the 7th of June, 1692, at the time of the earthquake which shook Jamaica and the neighbouring seas, the waves swept violently over the town of Port-Royal, and, in the space of three minutes, covered more than 2,500 houses with a depth of 33 feet of water. The ships were thrown in every direction on to the land, and the frigate *Swan* was stranded upon the roof of a house. In like manner, according to the statement of Acosta, the terrible wave which destroyed Callao in the year 1586, and carried a great ship right up on to the Lima road at a point 52 feet above the mean level of the sea, must have been altogether 89 feet in height. The Japanese, whose islands have often suffered from earthquakes and sea-bores caused by submarine shocks, say that these frightful phenomena are caused by the blows of the tail of a monster striking against the shore.

CHAPTER LXXIV.

MOVEMENT OF TERRESTRIAL WAVES.—VARIATIONS CAUSED BY THE INEQUALITY OF VERTICAL OUTLINE AND THE DIVERSITY OF ROCKS.—AREAS OF DISTURBANCE.—NOISE OF EARTHQUAKES.—FRIGHT OF MEN AND ANIMALS.

WHATEVER may be the nature of the first shock, whether it proceed from a sudden swelling up of lava or vapour, or whether it be caused by the falling in of upper strata upon the subjacent beds, the effects produced will always be the same as regards observers who are above the central point where the phenomenon is produced. They will experience a shock tending upwards. Even when falling with the ground, they might well fancy themselves raised, just as the aëronaut, whose balloon is falling towards the earth, sees the country mounting up towards him. Around the central point of disturbance, where the shock takes place in all its violence, and is felt vertically, in a manner more or less irregular, according to the number of shocks, the movements become more and more oblique, and are propagated across the strata of the earth in a direction which ultimately becomes perceptibly horizontal. The phenomenon of undulation which is produced in solid rocks is perfectly analogous to that which may be observed in water when a stone falls into it: a series of concentric waves is formed round the centre of the shock, and gradually disappears in the distance.

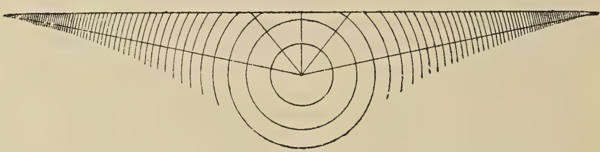
Terrestrial waves which are formed thus are very long and very flat, on account of the inflexible nature of the rocks through which the movement is transmitted. There does not, however, exist a single authentic measurement from which the dimensions of each wave may be deduced. The observer feels them pass rapidly under his feet during an earthquake, and is often able to notice the rocking of houses and towers, as well as the to-and-fro motion of church bells; but these movements are much more marked than those of the ground, and the movements of the earth have not been clearly distinguished on any occasion.

As to the direction followed by the wave, the tendency generally differs much, owing to the inequalities in the relief of the ground, from the regular direction which it would otherwise take. This direction is often very difficult to discover, owing to the want of necessary instruments and all the local circumstances which may modify the movement. It appears, however, that in mountainous countries, like Switzerland and the Pyrenees, the great undulations are propagated in the direction of the valleys. In striking against the tilted strata at the base of mountains, the corrugations of the soil act like the waves of a river dashing against the shores; they break up, and, changing their course, run along at the foot of the heights in the same direction as the stream of the valley. After this first rupture

in its movement, the undulation is communicated to the rocky masses of the mountain, and traverses their whole thickness. Beyond these lofty groups which disturb the movement, without always opposing to it any insurmountable obstacle, the vibrations corrugate the soil of the plains in a more regular way; but the intensity weakens proportionately to the square of the distance, and finally ceases to be perceptible to man. It must also be remarked that, at the periphery of the area of disturbance, the various shocks are generally produced at longer intervals than at the centre of the earthquake. The stronger the waves are, the more rapidly are they propagated, and thus it follows that between the different undulations, which generally become weaker and weaker, the interval always increases with the distance. In the centre the shocks all seem to blend together; towards the circumference they succeed each other like waves of slightly agitated water.

Among the causes which contribute to disturb the regular movement of terrestrial oscillations, the diversity of geological formations must also be reckoned. The swiftness of the transmission of the movement varies considerably, according to the composition of the rocks, the quantity of water they contain, and the hardness and elasticity of their layers. In order to explain the difference that exists between the various strata as regards the propagation of terrestrial waves, Mallet makes a striking comparison. If a person applies his ear to a railway rail which is struck with a violent blow at a point about a mile away, the compact iron transmits to him,

Fig. 226.—Transmission of Earth-waves.



nearly instantaneously, the wave of sound; immediately after, the observer will feel the undulation which is transmitted through the soil below the rail; then he will hear the noise transmitted by the atmospheric waves. If a canal flows along by the side of the railroad, a man plunged in the water would perceive the sensation of the blow, but not at the same time. In fact, the mean swiftness of the wave is 1,138 feet in the air, 4,692 in the water, and about 11,040 in a bar of iron.

It is a long-established fact that, during earthquakes, the shocks are propagated much more easily through compact rocks than through formations interrupted here and there by faults, fissures, caves, and soft ground. Mallet has proved these facts by direct and oft-repeated experiments made not far from the town of Holyhead in Wales. When mines of powder were exploded, the waves of disturbance, which were the more rapid as the charge was stronger, were propagated 951 feet a second in wet sand, 1,283 feet in a rock of friable granite, and 1,640 feet in a compact granite. Subsequently, Mallet, having made some direct observations as to the speed of transmissions of the waves during the earthquake at Calabria in 1857, found that it was about 820 feet a second. According to the same geologist, the starting-point of the shock was nearly three miles below the surface.

Without having made any exact investigations, the Hellenes and the Romans, who inhabited a soil frequently shaken by earthquakes, had discovered the fact that caverns, wells, and quarries retarded the disturbance of the earth, and protected the

edifices built in their neighbourhood. The town of Capua was, it is said, saved from the effects of earthquakes to a much greater extent than the adjacent cities, on account of the numerous springs in its gardens. Vivenzio also asserts that in building the Capitol the Romans took care to sink several wells in order to weaken the effect of terrestrial oscillations, and this plan succeeded in preserving the building from all damage. In like manner, the great constructions at Naples were built above vast caves, in which the force of the subterranean commotion is lost. Humboldt has described this curious fact—that at St. Domingo the inhabitants of the town spontaneously formed the idea, similar to that of the Greek and Roman naturalists, of digging out deep cavities as the only means of securing the stability of their dwellings.

Besides, as may readily be supposed, the longer, thicker, and lower the walls of the edifices are, the better they resist the shock. In all towns partly destroyed by earthquakes it is said that walls of this form were rarely demolished. When the undulations of the soil are propagated along the whole length of a block of low houses, there is hardly an instance in which the latter have been shattered; in countries, therefore, in which the movements of the soil generally assume the same direction, disasters can nearly always be provided against by setting the principal walls of the edifice in the direction of the terrestrial undulations.

The buildings which always suffer the most are those which have vaulted roofs, elevated in the form of domes or cupolas. The thrusting action of the heavy masses which crown the edifice causes the walls to separate when they are in a state of vibration from the effects of the subterranean shocks; the dome falls down inside, while the walls give way in an outward direction. A considerable area is covered with ruins all round the piece of ground on which the foundations stand, and, in consequence, the danger of being crushed becomes very great to any persons who are near the scene of the catastrophe. It was the earthquakes, and not the barbarians, which, according to the evidence of Mallet, destroyed so large a number of the palaces and temples of Rome during the period between the fifth and ninth centuries. In like manner, in more modern times, cathedrals and churches have often been overthrown, while other houses were saved. This well-known fragility of vaulted roofs, when shaken by undulations of the soil, will explain the cause of those frightful calamities which took place in various churches at the time of the earthquakes of Lisbon, Calabria, Caraccas, Mendoza, and San Salvador, when kneeling multitudes were crushed in the ruins.

The difference presented by rocks, as regards the speed with which the earthquake wave is propagated through them, and the various obstacles which impede it, has the effect of giving to the areas of perceptible disturbance shapes which are perfectly irregular. The movements, therefore, are not produced round the initial point with a regularity which can be at all compared to that of the wavelets which surround with their regular circles the centre of agitation in a disturbed water. Some earthquakes, as far at least as it is possible to judge from incomplete observations, seem to be propagated in very elongated ellipses. Others appear to have had for their area a space of a polygonal shape; thus the great paroxysm of the valley of Viége, which extended over 108,878 square miles, was felt three times farther in a northern than in a southern direction. Sometimes, outside the limits of the ground in a state of vibration, a region has been remarked which likewise shakes, like a kind of trembling islet surrounded by immovable land. At other times vast tracts have not experienced any apparent disturbance, whilst the ground all round them was trembling. On the 25th of July, 1846, a shock, of which

the severest influence was felt below St. Goar, on the banks of the Rhine, propagated its undulations in France and Germany over a surface estimated at 24,207 square miles; but a belt about 100 yards wide, between Pyrmont (Westphalia) and the right bank of the Rhine, appears to have remained immovable. According to the testimony of Humboldt, this fact of rocks not participating in the general movement of the surrounding formations has been frequently noted at the time of earthquakes in the Andes. The natives say of these intermediate zones, thus exempted from the vibrations of the ground round them, that they form a bridge (*hacen puente*), meaning by this that the oscillations are transmitted at a great depth below the inactive beds at the surface. It is difficult to imagine how such phenomena could take place, if the oscillations of the soil were caused by the

Fig. 227.—Area affected by the Earthquake of Viége in 1855.

movement of the waves in a subterranean sea of fire: if it were so, the upheaved terrestrial crust would undulate like an object floating on the surface of the water, and the burning waves, spreading out in a circle, would also give a perfectly round periphery to the superficial area of the earthquake.

To the two kinds of movement which have been observed in earthquakes—the upward shock and the long undulations spreading in the manner of marine waves —most of the *savants* since Aristotle also add the rotating or gyratory movement (*vorticosum*). The fact is, that in great cataclysms, when the different shocks cross each other in the ground, it has been thought that proofs of these twisting movements have been felt and even seen. At Quintero, in Chili, three great palm-trees, says Humboldt, twisted round one another like willow-wands, after each had swept

a small space round its trunk. Otto Volger, who does not believe in the existence of rotatory movements, mentions, however, the example of the steeple of Græchen, which twisted during the earthquake in the valley of Viége in 1855: however this twisting may have been caused either by a movement of the soil being communicated to the edifice, or by the want of equilibrium between the different parts of the steeple. Mallet also explains, by a difference between the centre of form and the centre of gravity, the gyratory movement which the stones of two small obelisks underwent during the earthquake at Calabria in 1783; he absolutely denies that the rotatory movement of the earth could take place, as the Italian naturalists had alleged.

As to the speed of the propagation of terrestrial waves, it was, even recently, very difficult to estimate, owing to the want of precision in the transmission of intelligence and the irregularity of the clocks in the different cities. Since 1853, the period at which the electric telegraph was applied for the first time in describing the shocks of the earthquake of Soleure, almost certain means are at our disposal for noting the passage of terrestrial waves in different localities. But up to our time it has scarcely been employed save in an exceptional way, and too often some of the desirable conditions of exactitude have been neglected.

The incomplete information gathered by Otto Volger about the great earthquake of Viége, in 1855, has warranted him in fixing approximately the speed of the undulation; it was at the rate of 2,861 feet a second from the centre of vibration as far as Strasburg, and 1,398 feet only in the direction of Turin. Robert Mallet, after having made his celebrated experiments on the speed of transmission of shocks in the rocks at Holyhead, instituted comparative investigations into the speed of the undulations of the great earthquake in Calabria in December, 1857, and found the average rate 774 feet a second. Since that time English observers established at Travancore, in the south of Hindustan, have estimated the movement of the undulations of a local shock at about 656 feet. The result of the calculations varying thus in proportion of one to four, it is impossible to indicate any average figure for the rate of transmission of terrestrial waves; it is certain that the rapidity, as well as the force and direction of the movement, differs according to the nature of the rocks and the position of the chains of mountains and valleys.

The noises which are heard during earthquakes differ in intensity still more than the other phenomena, and are much more difficult to classify, owing to the deep sensation that is felt when the earth is heard to roar, and the part which the imagination never fails to play when memory seeks to recall the past. The sounds, besides, heard at the time of the subterranean downfall sometimes exceed in their violence all known noises, and it is in vain to seek for suitable terms in which to describe them. In a general way, the noises of earthquakes may be compared to explosions of mines, discharges of artillery, peals of thunder, the rolling of carriages, the fall of avalanches, or the roar of cataracts. The diversity of these sounds is explained by the difference of the phenomena which may be taking place in the interior of the earth—the falling in and reboundings of rocks, the overflow of subterranean water, the irruption of masses of air through fissures, and distant echoes reverberating far and wide in the abysses. It is a strange thing that sometimes during one and the same earthquake certain persons cannot find terms strong enough to express the frightful noises that they have heard, while others think they have only felt the shock unaccompanied by the least sound. According to Otto Volger, this singular difference of sensation proceeds from the fact, well known to natural philosophers, that the scale of sounds perceived by the ear differs

in different individuals: just as in a meadow some persons do not hear the cry of the cricket, the note being too shrill for them, so, when the ground is shaken, those who are shaken with it would not all be able to hear the sounds produced by the cataclysm, on account of nothing but the deepness of their tone; the noises would be too deep for their ears. At a distance from the centre of the shock the noise gradually diminishes in intensity, but it always remains difficult to distinguish clearly, because the sound is transmitted with unequal speed both under the ground and in the atmosphere. Through the terrestrial strata the noise of the paroxysm travels with more rapidity than the shock itself; the shock is heard before it is felt; then, when the wave has passed, the sound is heard anew, being transmitted more slowly by the air. This inequality in the passage of the sound through the different mediums results in a great confusion of roaring and rattling, of which it is very difficult to give any just account. Observers have compared the noise of a distant earthquake sometimes to the rumbling of thunder, sometimes to a stormy wind, or the flapping of the wings of a large bird, and sometimes even to a discharge of musketry, the crackling of fire, or the whistle of a locomotive. One might fancy that in this manifestation of its mighty vitality nature makes use of all the sounds known to the human ear.

It is a widely-spread opinion, which, however, is not as yet undeniably confirmed, that animals manifest the greatest uneasiness at the approach of an earthquake. In certain countries, indeed, where these convulsions of the ground frequently take place, care is taken to observe attentively the ways of domestic animals, in order to detect the presentiment of the coming shock, and to prepare for the danger. It may perhaps be the case that slight vibrations, perceptible only to the delicate senses of animals, precede the subterranean downfalls; but very often it is probable that remarks of this kind are made after the catastrophe, and that imagination, excited by the fright, plays no inconsiderable part in the descriptions. Be this as it may, it is said that before an earthquake, rats, mice, moles, lizards, and serpents frequently come out of their holes and hasten hither and thither, as if smitten with terror. Even the crocodiles have fled away from their marshes, and hurried towards *terra firma*, roaring with fear. At Naples it is said that the ants quitted their underground passages some hours before the earthquake of July 26, 1805, and that the grasshoppers crossed the town in order to reach the coast; also that the fish approached the shore in shoals. A fact which is better attested is the fright of animals during the catastrophe itself. At the time of the earthquake which shook the valley of Viége, in 1855, the wild birds which most dread the fowler, such as owls, woodpeckers, and peewits, collected on the trees close to the dwelling-houses, and uttered plaintive cries, as if to demand the succour of man. Birds of long flight, swallows and others, at once took wing, and flew away to distant parts. For several days, also, the frogs ceased their croaking.

CHAPTER LXXV.

SECONDARY EFFECTS OF SHOCKS.—SPRINGS.—JETS OF GAS.—FISSURES.—DEPRESSIONS AND UPHEAVALS OF THE GROUND.

EARTHQUAKES very frequently exercise a considerable influence on the discharge of springs rising to the surface of the ground. A great many instances have been brought forward of springs, both thermal and cold, which have suddenly dried up or have increased in volume, accompanied by either an augmentation or diminution of temperature. These phenomena can be easily understood. After each downfall of rocks or fracture of the ground, the conduits through which the subterranean rivulets flow may be either altogether or partially obstructed; the water must then seek some other course, or must flow in a diminished stream through the old channel. Sometimes, also, the breaking down of some barrier which penned back the subterranean water opens up a free passage to it, and the spring is thus augmented in its discharge. Again, the waters of several subterranean currents of various temperatures may become mingled in consequence of some catastrophe, and the springs, therefore, are rendered either warmer or colder. In August, 1854, on the occasion of a violent earthquake in the Central Pyrenees, the heat of a spring at Baréges was raised from 64° to 82° (Fahr.), and its discharge, which was 2,729 gallons a day, increased to 6,338 gallons.

The effect more generally produced on springs by the occurrence of an earthquake is to render the water muddy by filling it with the *débris* which has fallen from the rocks disturbed, and been raised by the ascending body of water. During a series of observations made on the artesian well at Passy in 1861 and 1862, M. Hervé-Mangon ascertained that at the time of each of the subterranean shocks of Western Europe which was recorded by M. Perrey during the above-named interval, the water in the well was charged with sediment. On the 14th of November, 1861, the day on which a great earthquake occurred in Switzerland, the sediment in the well at Passy suddenly increased in quantity from 956 grains per cubic metre to 2,268 grains; the next day it decreased to 1,404 grains. This skilful chemist, by numerous processes, established several other striking coincidences between the impurity of the water and the vibrations of the ground. It is not at all probable that these geological facts are devoid of any mutual relation; it appears, on the contrary, that the artesian spring at Passy, and doubtless also most other springs gushing out to the surface, might be looked upon as actual "seismometers." At the time of earthquake shocks a kind of clearing out takes place of the natural or artificial conduits through which the spring water passes. According to the observations of M. François, who devoted considerable study to

the action of earthquakes on the mineral springs of the Pyrenees, the results of a shock are rarely felt for any length of time; after the lapse of two or three days the effects are no longer perceptible.

In all countries frequently affected by earthquakes, the inhabitants never fail to tell numerous stories as to sudden eruptions of water, mud, gas, or flames. Phenomena of this kind may be, in fact, produced in many districts, for shocks violent enough to close up or to enlarge the conduits of springs may equally well open out fresh channels, and thus afford an outlet to water pent up under deep layers of rocks. In like manner the hydrogen gases which are formed in the ground by the decomposition of organic matter may find an outlet by the breaking down of the rocks above them, and burn spontaneously, like the gases at Baku. Nevertheless, these curious eruptions, however probable they may appear, have not as yet been scientifically observed, and no idea seems to have been formed as to the real importance they might have. Even Mallet, the great advocate of the constant connection between earthquakes and volcanic phenomena, has not ventured to look upon these sudden jets of water, mud, and gas as facts on which science may depend. With regard to the sudden appearances of flashes and sparks, these may be explained in many cases by the collision of stones, which strike against one another as they fall.

Occasionally, during earthquakes, the ground is rent open for very considerable distances. In 1783, at the time of the terrible shocks which disturbed Calabria, the phenomena of ruptures of the ground ranked among the grandest and most frightful effects of the catastrophe. Whole mountain-sides, undermined by water, slid down *en masse*, and tumbled into the plains below, covering all the cultivated ground. Cliffs fell down in a body, and rocks opened, swallowing up the houses which stood upon them. At the western base of the granitic chain of the peninsula, the ground affected by the shock was cleft open for a length of more than 18 miles, and in some places, especially near Polistena, the fissure was several yards in width. Elsewhere other clefts were opened, one of which, near Cergulli, was no less than 131 feet in depth for a length of more than a mile, and 32 feet wide. In the environs of Rosarno, on the shore of the Gulf of Nicotera, well-like cavities were hollowed out with circular margins, doubtless caused by the gushing out of springs. Finally, districts with a level surface were cleft in every direction by cracks radiating in the shape of a star; the ground was broken up in a similar manner to mud which has cracked from the loss of its moisture. In February, 1835, on the occasion of the earthquake at Conception, in Chili, similar phenomena were observed: everywhere, says Fitzroy, contact ceased between the shifting ground of the plain and the bases of the rocky hills.

Mention should also be made of the great geological catastrophe which, in the year 1819, changed the shape of the district of Catch over a vast area. A part of the Great Rann sank down over an extent of some thousands of square miles, and, in consequence of the inroads of the salt water, it became a tract of land of an undetermined character, during drought a desert without water, and during the monsoons a salt lagoon. A rampart several miles in length, 164 feet broad, and 9 feet in height, was also raised in a straight line across one of the former mouths of the Indus. This rampart is called by the inhabitants of the adjacent districts "God's wall" (*Allah Bund*), to distinguish it from the Ally and Mora barriers, which the sovereigns of the country had constructed farther up stream. According to Mr. A. Barnes, the earthquake which produced this strange phenomenon of elevation and depression was felt over an area of more than 95,500 square miles.

With regard to the earthquake at Conception in 1835, the affirmative evidence

on the point is so abundant, that the raising of the coast at this place must be regarded as a positive fact; but it must remain unknown whether some enormous depression in the interior of the continent did not compensate for the temporary upheaval of the sea-coast. Still more recently, on the 23rd of January, 1855, at the time of an earthquake which violently shook New Zealand, and especially the two shores of Cook's Straits, the ground on which the town of Wellington stands was raised 23 inches, a cape in the vicinity was elevated nearly 10 feet, whilst a fissure of about 40 miles in length opened in the southern island on the other side of the straits, and the alluvial plain of a small stream sank considerably. Also, in 1861, the coast of Torre del Greco, at the foot of Vesuvius, was suddenly raised $3\frac{1}{2}$ feet for a length of more than a mile. All these are extraordinary phenomena;

Fig. 228.—The Rann of Catch and the Allah Bund.

and a just hesitation must at present be felt in venturing to give any explanation of them.

There is another geological fact which has been little studied as yet, which, however, must be perhaps attributed to oscillations of the ground: this is the curious arrangement that is assumed in some plains by the boulders, pebbles, and drifts of sand. Thus, in the Desert of Atacama, in many spots, regular figures are to be met with—circles, squares, or lozenges—composed of small fragments of quartz or other stone. In the entirely uninhabited plains of Safa, at the foot of the former volcanoes of Jebel-Hauran, M. Wetzstein likewise remarked a multitude of small figures with regular angles, formed something like mosaics, over very considerable areas. Must we look upon these designs as some immense symbolical work to be attributed to the ancient inhabitants of the district, or are they, in fact, the sports of nature, and phenomena similar in character to the figures shaped out by grains of sand agitated on vibrating plates? This question remains to be solved by future observers.

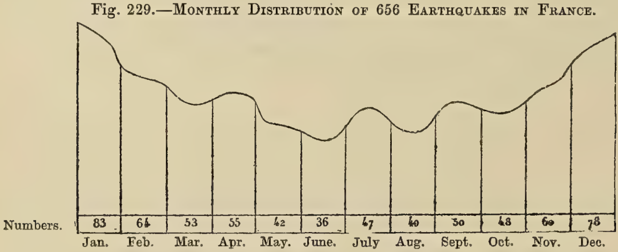
CHAPTER LXXVI.

PERIODICITY OF EARTHQUAKES.—THE MAXIMUM IN WINTER.—THE MAXIMUM AT NIGHT.—COINCIDENCE WITH HURRICANES.—INFLUENCE OF THE HEAVENLY BODIES.

FROM time immemorial it has been asserted by the natives of the countries which are most frequently ravaged by earthquakes, that these commotions bear some intimate relation to the movements of the atmosphere, and very generally coincide with certain meteorological conditions, such as rainy seasons, numerous storms, warm and damp winds. Nevertheless, most geologists, considering these oscillations of the ground to be nothing more than the half-exhausted quiverings of a great ocean of fire, have even recently denied the possibility of any such coincidence.

In 1834, Professor Merian, having classed, according to their appearance in the various seasons of the year, 118 earthquakes which occurred at Basle and in the

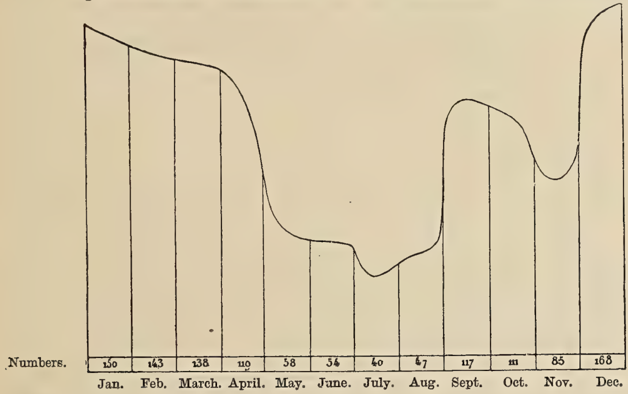
Fig. 229.—Monthly Distribution of 656 Earthquakes in France.



countries round it, ascertained, to the surprise of the scientific world, that these phenomena are much more frequent in winter than in summer. This fact, which was at first called in question, has since been indubitably established by the investigations of Alexis Perrey and Otto Volger. Only, in proportion as the list of shocks becomes more numerous, the difference between the winter maximum and the summer maximum tends to disappear, for the simple reason that, in the two opposite hemispheres, the seasons follow one another at six months' intervals, and that the various phenomena in connection with the seasons are thus brought into a state of equilibrium on each side of the equator. It is therefore necessary to study, in each region separately, the order in which the occurrence of earthquakes is divided among the different seasons. The comparative frequency of these pheno-

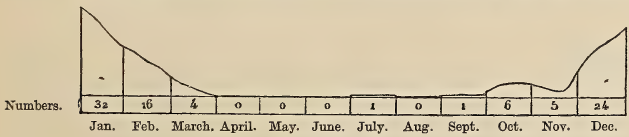
mena during the winter season is then much more easy to be observed. Thus the 656 shocks enumerated in France by Alexis Perrey up to the year 1845 are divided in the proportion of 3 to 2 respectively, for the half-years commencing in November and May. In the region of the Alps, where there are no volcanoes, the difference between the number of earthquakes in winter and summer is, on the other hand, enormous. By comparing the four months of May, June, July, and August, with December, January, February, and March, we see that the shocks are three times as numerous in the second season as in the first. In Italy, according to the same author, the difference was much less perceptible, since out of 984 earth-

Fig. 230.—Monthly Distribution of 1,230 Earthquakes in Switzerland.



quakes, 453 took place in the summer season, from April to September, and 531 during the winter half-year, from October to March. Nevertheless, even in this region, where most of the great subterranean movements are evidently in connec-

Fig. 231.—Monthly Distribution of 98 Earthquakes in the Mid-Valais.

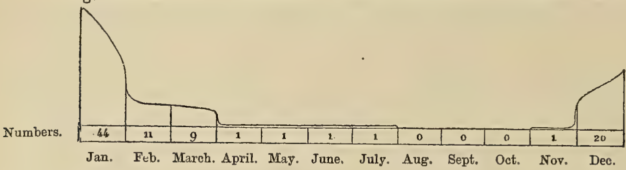


tion with volcanic action, these phenomena are perceptibly more frequent during the cold portion of the year.

If we limit ourselves to the study of some particular centre of shocks, the difference observed between the seasons in respect to the frequency of subterranean shocks is still more considerable. As an instance of this we may mention, on the authority of Otto Volger, the remarkable region of the Mid-Valais, where, out of a total number of 98 known earthquakes, one only took place in summer, whilst 72 were felt in winter. The proportion is nearly the same in the region of Hohensax, on the southern slopes of Säntis, not far from the former fork of the Rhine.

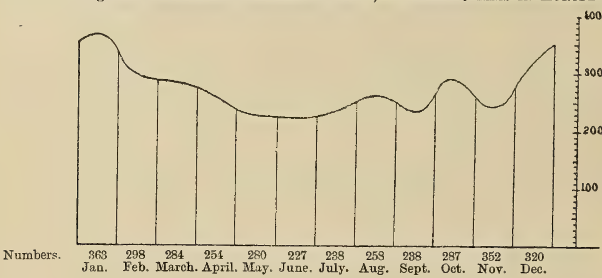
Not only are subterranean commotions more frequent in winter than in summer, at least in the regions of Central Europe and on the coasts of the Mediterranean as far as Asia Minor and the Caucasus, but this remarkable fact has also been observed—that the shocks are felt more frequently at night than in the day, and this holds good in all seasons of the year. In all earthquake regions this is uniformly the case. In Switzerland, out of 502 earthquakes, the date and time of which are known, only 182 took place between six o'clock in the morning and six o'clock in the evening; 320—that is nearly double—were felt during the twelve hours of the night. There is, therefore, for every diurnal period, a series of alternations resembling those of the annual period; but there is, in truth, no reason for astonishment in this, as, in an entirely general point of view, every day, in its rain,

Fig. 232.—Monthly Distribution of 98 Earthquakes in Southern Santis.



its storms, and all its meteorological phenomena, may be looked upon as an epitome of the whole year. Looking at it in a certain way, mid-day is summer, and midnight is the winter of each diurnal revolution. Have we not, then, a good right

Fig. 233.—Monthly Distribution of 2,249 Earthquakes in Europe.



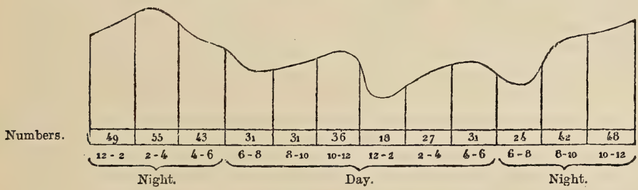
to infer, from the regular fluctuation of subterranean agitations, these fluctuations corresponding with the lapse of seasons and hours, that these great events depend, at least in certain countries, on some external phenomena, and not on the tremblings of a sea of lava? "Are they not," as Volger says, "connected with the whole body of laws which govern the return of light and darkness, heat and cold, snow and rain, drought and running water?" The greater number of earthquakes would thus be facts essentially connected with the conditions of climate.

It is also related that, during the hurricanes in the West Indies, the ground is severely shaken, as if the wind, which tears down trees, overthrows buildings, and drives the waves into immense waterspouts, had also laid hold of the layers of the rocks, and had shaken them on their bases. Is it the fact that the inhabitants, under the influence of terror, fancy that the ground itself participates in the

immense convulsion? Such hallucinations would not seem very wonderful when we consider that at each fresh fury of the cyclone nothing but death is expected. Nevertheless, the evidence relative to this coincidence between hurricanes and earthquakes is so abundant and positive, that it is difficult not to put faith in it. In 1844, on the occasion of a hurricane which destroyed hundreds of vessels in the roads of Havannah, a shock, which was not connected with any volcanic phenomenon, agitated the ground of the island. Still more recently, during the cyclone of 6th September, 1865, which ravaged Guadaloupe, the Saintes, and Marie-Galante, the earth suddenly shook at the most terrible moment of the tempest, and several houses were thrown down. What is the cause of this coincidence between earthquakes and cyclones? Does the electric storm itself penetrate into the depths of the earth? or do the torrents of rain produce subterranean downfalls? These are questions to which, at present, it is impossible to reply.

However this may be, we must at any rate admit that there are at least two classes of earthquakes; one proceeding from the pressure and eruption of vapour

Fig. 234.—Switzerland: Distribution of 435 Earthquakes every other Hour.



and lava, the other caused by the downfall of rocks; both, however, producing the same impression on the senses of man, and developing themselves in the same way over vast areas. Perhaps to these two classes of shocks it may be necessary to add a third—those, namely, which originate in the relations existing between our planets and the other bodies in space. Thus, according to Wolf, there is a constant relation between earthquakes and the spots on the sun. Finally, the investigations carried on with so much perseverance by Alexis Perrey prove unquestionably that the successive phases of the moon exercise considerable influence on movements of the ground. Like the ocean, the earth, too, has its tides. The frequency of earthquakes, even of those which are only revealed to us by the delicate instruments of M. d'Abbadie, augments, like the height of the flow of the tide, at the epoch of the syzygies. This frequency increases when the moon approaches the earth, and diminishes when it is farther away; in a word, the time when the sea oscillates with the greatest force is also the time when the earth itself most frequently trembles. "Our planet," says M. Boscowitz, "is engaged in a constant exchange of forces and influences with the heavenly bodies which, like it, occupy ethereal space."

CHAPTER LXXVII.

SLOW OSCILLATIONS OF THE GROUND.—DIFFICULTIES PRESENTED IN THE OBSERVATION OF THESE PHENOMENA.—CAUSES OF ERROR: EROSION OF SHORES, SWELLING AND SINKING OF PEATY SOILS.—INFLUENCE OF TEMPERATURE.—LOCAL UPHEAVALS.

THE solid ground, which people once considered as the symbol of immobility, is, on the contrary, in a state of constant oscillation. The crust of the earth, carved out incessantly by the various meteorological agents on one side, drawn by the other bodies revolving in space on the other, modified by water and pressed upon by vapours, gases, and molten matter, never ceases to undulate as a raft rising and sinking on the waves of the sea. At rare intervals there are great earthquakes; more often this undulation of the ground consists in mere vibrations, which are scarcely perceptible except by the aid of instruments. The terrestrial crust is not only continually shaken by these transient shiverings; it is, besides, actuated by uniform movements of incalculable force, which at some points raise it, and at others depress it, as compared with the level of the sea. Whilst we are busy on its surface, the earth itself is shifting under our feet.

The upheavals and depressions, which recall to mind the phenomena of organized bodies, often take place so slowly, that to verify them with any degree of certainty, successive generations of observers would require the lapse of many years, or even centuries. The "patient earth" seems to revolve inertly in space, and yet it is at work without intermission in modifying the form of its seas and its coasts. During each geological period, the continental surface, motionless in appearance, rises in some spots to a great height above the ocean, and, in others, it sinks beneath the water; everywhere, indeed, the ancient relief and outline of the ground are being slowly modified. In accordance with what law, in what geographical order, and at what comparative rate of progress do these gradual oscillations take place, which result, in the long run, in effecting a change in the general aspect of the globe? Science is not as yet in a position to give a positive answer to these questions. But, in the meantime, until geologists are able to estimate exactly the dimensions and progress of each wave of upheaval which is formed by the crust of the earth, it is, at all events, possible to bring together the principal facts which bear upon the subject of the oscillatory movements of continents and the bed of the sea.

Small broken shells, the scattered remains of polypes, almost invisible grooves marked here and there on the sides of rocks—all the signs, which most people would pass by with indifference, are become, thanks to the patience and sagacity of

observers, so many undeniable proofs of the regular movements of the ground. It is, however, only on the sea-coast and in the vicinity of seas that *savants* can positively verify these manifestations of the vitality of the globe. Considering the ocean as a fixed level-mark, which is almost motionless in relation to the elevated or depressed masses of the land, they can easily prove the general elevation of a region by noticing on the shore the parallel lines formed at different epochs by the friction of the sea-water. But farther inland the marks of the same kind which are traced out on their banks by rivers and lakes are very seldom able to furnish incontestable evidence of vertical oscillations of the soil. The more or less shifting level of lakes and running water depends on several geological circumstances, and it is only when all these circumstances are perfectly well known that the ancient terraces and slopes of erosion which exist in fluvial and lacustrine basins can be made to serve as marks to measure the progress of terrestrial oscillations. As a matter of fact, geologists are, therefore, compelled to limit themselves to bringing under notice those oscillatory movements of the earth's crust which are taking place on sea-coasts.

In studying the oscillations of the earth, it is important to be very carefully on our guard against the numerous causes of error which arise from the eternal combat which is always taking place on the shore between the land and the sea. Neither the gradual encroachments of alluvial shores, nor the progressive erosions which, in so many places, the coast has to undergo from the sea, are to be considered, without due examination, as proofs of the upheaval or subsidence of a region. The sand which is driven up by the waves of the sea, and the alluvium which is drifted down in the currents of rivers, are deposited on most low coasts in sufficiently considerable quantities for the belt of shore to increase constantly in breadth. Even where this zone sinks slowly with the land adjacent, as is taking place at the north of the Adriatic, the alluvium may nevertheless form on the shore a kind of cushion, and may defend the plains of the interior against the waves of the sea. On the other hand, there are a great many steep beaches and cliffs which, being assailed in front by the waves and the tide, and worn away obliquely by lateral currents, recede gradually before the inroads of the sea; but in cases of this kind it is usually impossible to detect the slightest depression in the general level of the country. Gentle geological elevation of the ground may, indeed, actually coincide with a falling back of the shores. The coasts of Aunis and Saintonge present an example of this apparent anomaly.

In movements of the soil it is necessary also to distinguish those which are produced by the slow pressure of subterranean forces, and those which are occasioned by temporary causes, such as the greater or less quantity of water contained in the surface layers, the activity of evaporation, and the bringing into cultivation of the country. Thus, when peat-mosses form in the low-lying lands of the valleys, taking the place of lakes and marshes, they hold the water in their masses of moss just as an immense sponge, and, gradually swelling, ultimately rise to a height of several feet above the former level of the soil. On the other hand, those tracts of peat-moss which have been dried by draining operations gradually sink; the mosses wither, die, and are reduced to dust. One might fancy that the soil was slowly sucked towards the interior of the earth by some secret force.

There is, however, no reason to be astonished at these alternate phenomena of swelling and shrinking which are afforded by peaty soil, as a mere variation of temperature is sufficient to produce similar results in the compact strata of mountains. In the day-time the particles of rocks dilate under the influence of the

solar rays; in the night-time they become cool, and contract in consequence of radiation, and the total mass sinks to a very slight extent, which is sometimes perceptible by means of instruments. Thus Moesta, the Chilian astronomer, has been enabled to ascertain that the National Observatory of Chili, situated on the hill of Santa Lucia, near Santiago, rises and descends alternately in the space of twenty-four hours. The daily oscillations of the rock, which in turn dilates and shrinks, are, indeed, considerable enough to render it necessary to introduce this element of calculation into the mathematical formulæ devoted to the regular observations. Similar phenomena, but occasioned by different causes, are produced under the Observatory of Armagh, in Ireland. After heavy rains, the hill on which the edifice stands rises perceptibly; then, after active evaporation has got rid of the extra water contained in its pores, the hill again sinks.

The shocks of greater or less violence communicated to the soil in volcanic districts produce alterations in the level which are much more considerable than the slight oscillations caused by the heat of the sun or the various atmospheric agents. But these alterations of level are none the less merely local phenomena, and although they are doubtless connected with the same class of facts as the slow upheavals and depressions, they must clearly be distinguished from the long-protracted movements which bulge up the crust of the earth under whole continents. As an instance of the local undulations which are mere accidents in the history of the planet, we may mention that which the earthquake of Conception caused to take place temporarily in February, 1835, at the Isle Santa Maria and the adjacent coasts of the Chilian mainland. An enormous mass of earth was suddenly elevated. The shore nearest the town was raised perpendicularly a yard and a half, while the island, uprooted, so to speak, by the violence of the subterranean shock, was upheaved obliquely 2½ yards at its southern point, and 3½ yards at its northern extremity. Two months afterwards the shore at Conception was scarcely 23 inches above its former level, and the island had also sunk in proportion. Finally, towards the middle of the year, every trace of the upheaval had disappeared, and the sea-water came exactly up to the same winding line of *débris* which it washed before the catastrophe.

The famous columns of the supposed Temple of Serapis, which rise on the shore of the Mediterranean, not far from Pozzuoli, likewise bear on their marble shafts proofs of purely local oscillations. Spallanzani has shown that these columns, the bases of which were surrounded with rubbish, must at some former date have been immersed in the water of the sea to a depth of about 21 feet; for up to this height the calcareous cases of the serpulæ may be noticed on the shafts, and also the innumerable holes that the pholades have hollowed out in the thickness of the marble, which is eaten away circularly by the waves. The temple having been repaired in the reign of Marcus Aurelius, must certainly at that time have been above the level of the sea. It is not known at what date it sank, together with the hillock on which it stands. It might, perhaps, have taken place during the year 1198, in which year the *Solfatara* of Pozzuoli produced an eruption. With regard to the emergence of the colonnade from the water, it is probable that it happened in the year 1538, at the time when the Monte-Nuovo made its appearance. If these supposed dates are the real ones, the lower half of the Temple of Serapis must have been bathed for 340 years in the waters of the gulf. But this event can only have been caused by some local agitation of the earth; for, during the same period, the adjacent coasts of Naples have not altered their level to any perceptible extent.

CHAPTER LXXVIII.

UPHEAVAL OF THE SCANDINAVIAN PENINSULA; OF SPITZBERGEN; OF THE COASTS OF SIBERIA, OF SCOTLAND, OF WALES.

ON all those coasts where heaps of modern shells now left dry, and the ledges cut out at different heights in the faces of the cliffs, furnish unquestionable testimony of a progressive upheaval of the ground, *savants* who desire to study the progress of the phenomenon must, of course, do so both by direct measurements and by comparing the levels taken at longer or shorter intervals. More than a hundred and thirty years ago, Celsius, the Swedish astronomer, formed the idea of resorting to these means, not with the intention of verifying the growth of the Scandinavian peninsula—a fact which to him did not seem at all probable—but in order to prove the supposed alteration in the level of the waters of the Baltic Sea. He was aware, from the unanimous testimony of the inhabitants of the sea-coasts, that the Gulf of Bothnia was constantly diminishing both in depth and extent. Old men pointed out to him various points on the coast over which, during their childhood, the sea used to flow, and, besides, showed him the water-lines which the waves had once traced out farther inland. Added to this, the names of places, the position more or less upon the mainland of former ports now abandoned, and of edifices built once upon the shore, the remains of boats found far from the sea; lastly, the written records and popular songs, could leave no doubt whatever as to the retreat of the sea-water. At this epoch, when *savants* still believed in the immovable solidity of the rocky framework of the globe, Celsius was naturally bound to attribute the constant growth of the sea-coast to the gradual depression of the level of the sea. In 1730 he felt himself warranted, by comparing all the evidence he had collected, in propounding the hypothesis that the Baltic sunk about 3 feet 4 inches every hundred years. Then, in the course of the following year, having, in company with Linnæus, made a mark at the base of a rock in the Island of Loeffgrund, situated not far from Jefle, he was able personally to verify, thirteen years afterwards, that the retreat of the Baltic Sea was taking place quite as rapidly as he had supposed. The difference of level observed during these thirteen years was 7 inches, or 4 feet 5 inches for a century. From 1730 to 1839 the upheaval of Loeffgrund amounted to 2 feet 11 inches only.

Celsius was accused of impiety by the divines of Stockholm and Upsala. The parliament, indeed, wished to cut the matter short by a vote ; the two orders of peasants and nobility declared themselves incompetent in the matter; whilst the representatives of the clergy, followed timidly by the burgesses, condemned the new opinion as an abominable heresy. Nevertheless, the geologists who, since the

last century, have visited the coasts of Sweden, have been compelled to verify and complete Celsius's observations. They have, however, been forced to reject the first hypothesis of the gradual subsidence of the water, and to recognise as a fact that the movement, attributed in error to the liquid mass of the Baltic, was that of the continent itself. As, indeed, had been already asserted in 1740 by Antonio Lazzaro Moro, an Italian *savant*, it was the earth, and not the sea, which was the moving and shifting element. In fact, if the sea-level was progressively sinking, as was once supposed, the water, the surface of which, owing to gravity, must always remain horizontal, would retreat equally all round the Scandinavian peninsula, and on all the sea-shores. But this is not the case. At the northern extremity of the Gulf of Bothnia, at the mouth of the Tornea, the continent is emerging at the rate of 5 feet 3 inches a century, but by the side of the Aland Isles it only rises $3\frac{1}{4}$ feet in the same time; south of this archipelago it rises still more slowly; and farther down, the line of the shore does not alter as compared with the level of the sea. The terminal point of Scania is gradually being buried under the waters of the Baltic, as is proved by the forests which have been submerged. Several streets of the towns of Trelleborg, Ystad, and Malmoe have already disappeared; the latter has sunk 5 feet 2 inches since the observations made by Linnæus, and the coast has lost, on the average, a belt 32 yards in breadth.

On the west coasts of the Scandinavian peninsula the phenomena proving a recent upheaval of the ground are just as numerous as on the eastern shores; but the rapidity of the ascending movement has not yet been measured, although it is certainly less considerable than in Sweden. The terminal point of Jutland, bounded by an ideal line tending obliquely from Frederica towards the north-west, rises, according to Forchhammer, 11·70 inches a century. At Christiania the increase is perhaps still less, for, according to Eugène Robert, the pavement of the ancient town appears to have remained stationary for three hundred years. Lastly, farther to the north, the present position of several edifices situated in the Island of Munkholm, near Trondhjem, proves, as Keilhau the geologist says, that during a thousand years the elevation of the ground has been less than 20 feet. This is all that is positively known. Nevertheless, a comparison of the various lines of level, and an examination of all the other indications of a slow upheaval, seem to show that, in spite of the numerous inequalities in the rate of progress of the phenomenon, that portion of the coast which is nearest to the pole is rising the most rapidly out of the water. Elevated beaches, which can be traced by the eye like the steps of an amphitheatre, are arranged in stages at various heights on the slopes of the mountains. Heaps of modern shells are found at heights of 500 to 650 feet above the level of the sea, and the great branches of pink coral formed by the *Lophohelia prolifera*, which lives in the sea at a depth varying from 1,000 to 2,000 feet, are now raised up to the base of the cliff. The pine woods, too, which clothe the summits, are continually being upheaved towards the lower snow-limit, and are gradually withering away in the cooler atmosphere; wide belts of forest are composed of nothing but dead trees, although some of them have stood for centuries.

The whole body of facts known on the subject of the movements of the ground of Scandinavia will, therefore, warrant *savants* in comparing the whole peninsula to a solid plane turning round a line on which it rests, and raising one of its ends so as to lower the other in the same proportion. The Gulfs of Bothnia and Finland, like vessels tilted up out of the horizontal, slowly pour their waters into the southern basin of the Baltic. Fresh islets and ranges of isles appear in succession, rocks are laid dry, and if the elevation of the bed of the sea continues to take place

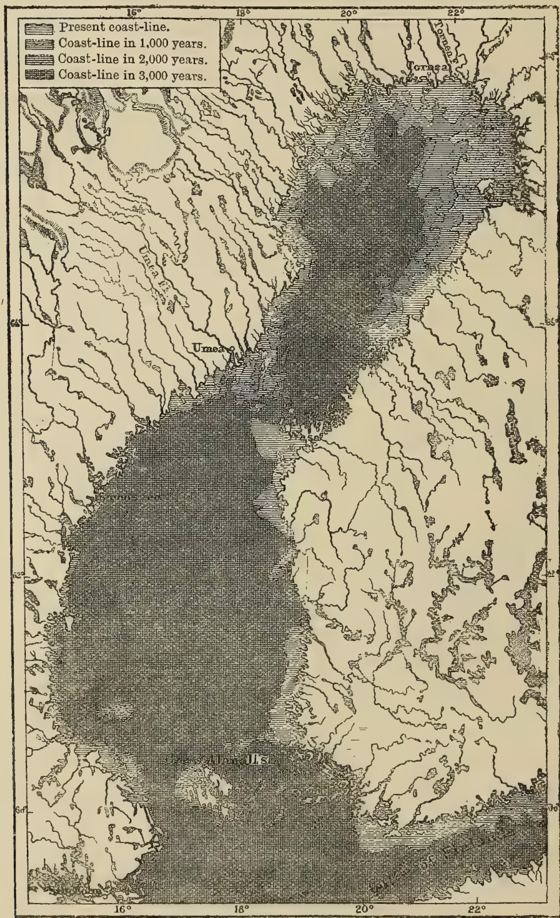
with the same regularity as during the historic ages, it may be predicted that in three or four thousand years the archipelago of Qvarken, between Umea and Vasa, will be changed into an isthmus, and the Gulf of Tornea will be converted into a lake similar to that of Ladoga. Later still, the Aland Isles will become connected with the continent, and will serve as a bridge between Stockholm and the empire of Russia. It is, besides, very probable, if not certain, that the great lakes and innumerable sheets of water which fill all the granite basins of Finland have taken the place of an arm of the sea which once united the Baltic to the great Polar Ocean. The erratic blocks of granite scattered about all over Russia can only have been carried thither by trains of ice which have made their way over the sea from the mountains of Sweden. The shells belonging to polar waters, which are found as far as the basin of the Volga, also testify in favour of the existence of a former arm of the sea. The name of Scandinavia itself signifies "Isle of Scand," and the name of Bothnia (Botten) proves that these coast provinces were formerly a marine bed. Here philology steps in to aid geology and tradition.

Moreover the Baltic Mediterranean formerly communicated with the North Sea by a wide channel, the deepest depressions of which are now occupied by the Lakes Maler, Hjelmar, and Wenern. Considerable heaps of oyster-shells are found in several places on the heights which command these great lakes of Southern Sweden. On the rocks now laid dry, which surround the Gulf of Bothnia, banks of these molluscs have also been discovered exactly similar to those of Norway and the western coasts of Denmark. With regard to the celebrated *kjoekkenmœddings* of the Danish islands, they are in great part composed of oyster-shells, which the inhabitants, in the age of stone, evidently used to collect in the bottoms of the neighbouring bays. It has been proved by the investigations of Baer that the oyster cannot live and grow in water holding more than thirty-seven parts in a thousand of salt, or less than sixteen or seventeen parts in a thousand. Now, the Baltic Sea, into which its numerous tributaries bring a large quantity of fresh water, does not contain, on the average, more than five parts in a thousand of salt; and, indeed, in some of the gulfs, the water, now devoid of all its former inhabitants, has become entirely fresh. And yet—the heaps of oyster-shells prove it—the Baltic Sea and the inland lakes were once as salt as the North Sea is at the present day. Whence, then, could this saltness proceed, except from some former strait which occupied the depression in which the Swedish engineers have dug out the Trolhatta Canal? Besides, when the sluices were being constructed, there were found, not far from the cataracts, and at a height of 40 feet above the Cattegat, various marine remains, mingled with relics of human industry—boats, anchors, and piles. According to Baer, it is not, at the most, more than five thousand years before our century that we must date the closing up of the straits which used to exist between Southern Sweden and the great mass of the northern plateaux.

Since Leopold von Buch has placed beyond all doubt the important fact of the gradual upheaval of the northern portion of the Scandinavian peninsula, several geologists have ascertained that the elevation does not take place in a mode that is perfectly uniform. During bygone centuries the movement has sometimes been accelerated and sometimes slackened, as is proved by the inequality of the elevated sea-beaches which run along the sides of the mountains on the coasts of Norway. Some of these steps or shelves that the waves have carved out in the rock are wide and gently inclined; others are abrupt, and can scarcely be distinguished from the slopes above them. Lastly, the measurements made by M. Bravais along

the lines of erosion of Altenfjord have proved that they are not parallel, and that the rocky masses situated at the ends of the gulfs have been more energetically upheaved than the layers lying nearer the sea. Thus the upper bank of Altenfjord has risen at the eastern end to a height of 219 feet above the level of the

Fig. 235.—Elevation of the Bed of the Gulf of Bothnia.



sea, but at the entry of the bay it has only risen 91 feet. In like manner, the lower shelf, throughout the whole of its immense circuit round the gulf, presents a slight inclination towards the sea, being no less than 88 feet high on the east, and only 45 feet on the outer promontories. Thus the action of upheaval is

evidently stronger in the vicinity of the mass of mountains than it is on the coast; but this does not afford any sufficient reason for saying that at a certain distance to the west, under the bed of the sea, the movement of the ground entirely ceases.

Carl Vogt has propounded an ingenious hypothesis to account for this inequality of elevation. According to his theory, rocks of various natures—schists, sandstones, or limestone—which compose the mountains of the Scandinavian peninsula, incessantly swell in consequence of the infiltration of snow-water, and owing to fresh crystallizations taking place, by means of moisture, are gradually converted into masses of stratified granite. This hypothesis, which has been much discussed by geologists, would certainly explain the raising of the lines of erosion of the Norwegian coast near the groups of mountains, but it would fail to account for the intervals of comparative repose, and especially for the sinking of the ground, which many geological facts prove to have taken place during the Glacial period. It is, therefore, necessary to admit that other forces have been in action in the solid mass of Scandinavia.

Added to this, we must not lose sight of the fact that the upheaval of this peninsula is not an isolated event, and that the other countries of the North of

Fig. 236.—Bank of Altenfjord.

Europe and Asia, notwithstanding the diversity of their rocks, all appear to be actuated by a similar movement of ascension. The islands of Spitzbergen exhibit generally, between the present sea-shore and the mountains, former sea-beaches which are gently inclined, and half a mile to two miles and a half in breadth, on which are found, up to a height of 147 feet, heaps of bones of whales and shells of the present period. These remains, surrounding all the snow-clad slopes of Spitzbergen, prove that this archipelago, like Scandinavia, is gradually emerging from the waves of the Polar Ocean. The northern coasts of Russia and Siberia are likewise rising, as is attested by popular tradition and the evidence of learned travellers. Keyserling, Murchison, and Verneuil have found, at points 250 miles to the south of the White Sea, on the banks of the Dwina and the Vaga, beds of sand and mud containing several kinds of shells similar to those which inhabit the neighbouring seas, and so well preserved that they had not lost their colours. In like manner, Middendorf states that the ground of the Siberian *toundras* is in great part covered with a thin coating of sand and fine clay, exactly similar to that which is now deposited on the shores of the Frozen Ocean; in this clay, too, which contains in such large quantities the buried remains of mammoths, there are also found heaps of shells perfectly identical with those of the adjacent ocean. Far inland, besides, trains of drift-wood are seen, the trees forming which once grew

in the forests of Southern Siberia; these trees, having been first carried into the sea by the current of the rivers, have been thrown up by the waves on the former coasts, which are now deserted by the sea. It is this half-rotten wood which is called by the natives "Noah's wood," fancying that they have before them the remains of the ark of the deluge. More than this, there are also direct proofs of the upheaval of Siberia. The Island of Diomida, which Shalaourof noticed in 1760, to the east of Cape Sviatei, was found to be joined to the continent at the date of Wrangell's voyage, sixty years later. It is, besides, very probable that this upheaval of the ground is prolonged to the east over a great portion of the circumpolar land of North America, as far as Northern Greenland; for numerous indications of this phenomenon have been recognised in the Arctic isles scattered off the coasts of the continent. At Port Kennedy, Mr. Walker found shells of the present period at a height of 557 feet above the sea; a bone of a whale lay at a height of 164 feet.

The cliffs of Scotland also present phenomena similar to those of Scandinavia. Parallel water-marks traced out by the waves on the escarpments of rocks, and collections of shells peculiar to the neighbouring seas, attest the gradual elevation of this portion of Great Britain. The elevation, too, must have been of a much more regular character than that of the coasts of Norway; for, according to Robert Chambers, not the slightest variation of level is noticed on the ancient terraces. This ascending movement is still continuing; for it has been ascertained that the marine cliffs which were once situated above the estuaries of the Forth, the Tay, and the Clyde, contain not only organic remains of recent ages, but also heaps of pottery of Roman origin. The former Roman port of Alaterva (Cramond), the quays of which are still visible, is now situated at some distance from the sea, and the ground on which it stands has risen at least 24½ feet. In other places the *débris* scattered on the bank show that the coast has risen about 26½ feet. Now, by a remarkable coincidence, the ancient wall of Antoninus, which, at the time of the Romans, served as a barrier against the Picts, comes to an end at a point 26 feet above the level of high tides. The general upheaval of the region may therefore be estimated at 0·195 inch a year; but since 1810 the movement has become more rapid, as is proved by the tide-meters at the port of Leith, and it is, at present, at the rate of 0·546 a year. Farther to the south, on the sides of the mountains of Wales, there are numerous indications of the presence of the sea during the present period. Mr. Darbishire has discovered, not far from Snowdon, at a height of 1,357 feet, a bed of drift containing fifty-four species of shells of similar kinds to those still existing in the northern seas of Europe; the same soil was, however, found at a point 650 feet higher, but devoid of shells.

Thus, from Wales to Spitzbergen and the eastern coasts of Siberia, the ground has continued to rise slowly during a portion of the Glacial period, and also during the present epoch. The area of upheaval includes a portion of the earth's surface which is not less than 160 degrees of longitude. In the face of these facts, are we to consider the phenomena of upheaval as mere local accidents produced by the swelling of rocks and volcanic shocks, or must we look upon them as the results of some general cause acting in various ways over the surface of the whole planet? The latter hypothesis appears to us to be the more probable.

CHAPTER LXXIX.

UPHEAVAL OF THE MEDITERRANEAN REGIONS.—FORMER LIBYAN STRAIT.—COASTS OF TUNIS, SARDINIA, CORSICA, ITALY, AND WEST FRANCE.

THE countries of the South of Europe certainly possess a more gracefully indented outline than any other regions on the face of the earth. Bays, gulfs, and inland seas penetrate them in every direction. The peninsulas which they throw out present the greatest variety of contour and aspect, and they have thus become, as it were, imbued with vitality, owing to their numerous articulations, similar to those of an organized body. Corresponding with this multiplicity of external shapes are the singular irregularities and exceptional contrasts in the movements of the ground. A certain complication is here and there manifested between the upheaved regions and those which are subsiding. Nevertheless, a sufficient number of observations have been collected to warrant us in admitting, in a general way, the elevation of most of the countries which surround the basin of the Mediterranean. These regions, which in several places have been caused to oscillate by volcanic forces, constitute a considerable area of upheaval, extending from the deserts of the Sahara to Central France, and from the coasts of Spain to the steppes of Tartary. The mountainous peninsula of Scandinavia is situated in the middle of the upheaved regions of Northern Europe, and, by a kind of polarity, the long depression of the Mediterranean occupies the centre of the vast areas in the South of Europe and Northern Africa, which are gradually rising.

This immense space was once bounded, towards the tropical zone, by another sea, or at least by a strait several hundreds of miles in width, which commenced at the Gulf of Cabes, and, filling up the depressions of the Berber Sahara, joined the Atlantic opposite the Canaries. In 1863 Escher von der Linth and Desor ascertained that the sands of these regions are entirely identical with those of the nearest Mediterranean shores, and contain the same species of shells. One of these witnesses of the past, the common cockle (*Cardium edule*), is found, not only on the surface of the ground, but also at some depth, and likewise up to a height of 900 feet upon the sides of the hills. The Algerian Sahara has, therefore, risen to this extent during a recent geological period. Various depressions, the surface of which is lower than the level of the Mediterranean, have been gradually separated from the sea, and, in the present day, they exhibit nothing but marshy pools or interminable plains. At a recent and perhaps historical epoch, Lake Tritonis of the ancients, now the Sebkha-Faraun, into which flowed the Igharghar, has ceased to be a prolongation of the Gulf of Cabes, and has become a mere marsh. It was the last remnant of the arm of the sea which separated the mountainous regions of Atlas from the African continent, both so distinct in their general character, as well as in their fauna and flora. To the existence of this

African Mediterranean, which is now replaced by white sands, beds of salt, and rocks devoid of verdure, MM. Escher von der Linth and Lyell in great part attribute the enormous extent of the former glaciers of Europe. It is, in fact, very natural to think that, before the drying up of this inland sea, the masses of air blown to the north would become saturated with moisture while passing over the water, and, rising gradually to the higher regions, would constantly convey fresh layers of snow to the summits of the Alps, instead of melting the snow, as the *föhn* now does, heated as it is by the reflection from the burning sand of Africa. It is, however, possible that the Swiss mountains have decreased in height since the Glacial period. The same slow oscillation of the ground which emptied the Libyan Mediterranean has, perhaps, by its reaction lowered the foundations of the Alps, and brought them nearer to the level of the sea.

On the coasts of the Mediterranean the indications which would lead us to infer the fact of some upheaval of the ground are plentiful enough. Thus the shores of Tunisia are constantly encroaching on the sea. The ancient ports of Carthage, Utica, Mahedia, Porto-Farina, Bizerta, and others, are now filled up. The bays are effaced the points advance further and further into the sea; and these phenomena take place with a rapidity sufficient to show that we are witnessing the effect of a vertical impulse similar to that which once upheaved the beds of the Saharan seas. In like manner, Sicily appears to be constantly elevated by the forces in action under the beds of its surface. On the heights which command Palermo, caves have been observed at an elevation of 180 feet, which have been hollowed out by the sea during a period characterized by existing species of shell-fish. On the eastern coast of the island, Gemellaro has recorded a recent upheaval of more than 42 feet. In Sardinia, not far from Cagliari, De la Marmora points out, as existing at heights of 242 and 231 feet, deposits which contain remnants of pottery mixed with modern shells, which deposits, in his idea, were on a level with the sea at a date when the island was inhabited by man. Certainly, M. Emilien Dumas, an excellent observer, considers that these remnants of pottery and heaps of shells are nothing but the remnants of the cooking of food, similar to the *kjoekkenmœddings* of Denmark. If this be the case, there would be nothing to prove that Sardinia was upheaved at any recent epoch. But are the enormous banks of oyster-shells which cover the ground at the Lake of Diana, 6 feet above the level of the sea, and are continued far under the water, to be considered as nothing but the *débris* of Roman banquets? Such an idea does not, at least, appear at all probable to Aucapitaine and some other observers.

The facts of upheaval brought forward by geologists as regards the other regions of the coast of the Mediterranean are not as yet sufficiently verified, and it cannot be positively asserted that these shores have risen above the sea during the present period. Nevertheless, the body of evidence is of considerable importance, and merits serious consideration. Thus, round the former Island of Circe, now become a promontory of Tuscany, the rocks, which have much the appearance of a former sea-beach, are pierced by *pholades*. With regard to the discovery of banks of modern shells made by Risso near Villefranche, at the extremity of the Cape of Saint-Hospice, Emilien Dumas disputes its scientific value. Nevertheless, it is plain that this coast, and the whole of the adjacent shore as far as Spezzia, were covered by sea-water at a recent geological epoch. All that is necessary to prove this is to examine the caves of Mentone, of Ventimiglia, and of the Cape of Noli, which were hollowed out by the waves at some former date, and open like rows of arched doors and windows along the façade of some palace.

The southern coasts of France do not afford any direct evidence of an upheaval of the soil; but various indications possess a value which cannot be disputed. Astruc, of Languedoc, brings forward a great number of facts, which prove that, at the time of the Romans and in the Middle Ages, the marshes extended much farther inland. The ancient Roman road from Beaucaire to Béziers describes a wide curve towards the north, doubtless to avoid the plains on the shore, which were then entirely under water. Ancient cities with Gallic names—as *Ugernum* (Beaucaire) and *Nemausus* (Nismes)—are found along the ancient road; whilst all the places situated to the south bear Latin or Roman names—as Aigues-Mortes, Franquevaux, Vauvert, and Frontignan (*Frons stagni*)—and appear, therefore, to be of more modern origin. It is, besides, proved by various documents that ancient ports have filled up, and have been converted into *terra firma*. Astruc also points out the remarkable fact that the Romans, who highly appreciated thermal springs, were not aware of the abundant wells of Balaruc, although the eddies of steam could not have failed to point them out if they had not been covered at that time by the waters of the Lake Thau. This is an important argument in favour of the hypothesis of a gradual elevation of this part of France.

Beyond the Mediterranean basin, this movement of general upheaval appears to continue towards the north and west. Thus, at Seixal, opposite Lisbon, they have been compelled to cease building ships of the line on account of the increasing diminution of the water, which is attributed both to the deposits of mud and also to the upheaval of the rocks. On the Atlantic coasts of France a great number of phenomena of a similar nature have also been adduced. To many geologists, especially to Bravais, it seems probable that the whole of France, agitated by a slight and almost imperceptible tremor, is being slowly upheaved on the southern side, and turns on a base-line passing through the peninsula of Brittany. At all events, the coasts of Poitou, Aunis, and Saintonge appear to have risen since the commencement of the historical epoch. Guérande, Croisic, Bourgneuf, and Sables-d'Olonne show upon their shores unquestionable traces of recent elevation. The former Gulf of Poitou, the entrance of which, two thousand years ago, was not less than 18 to 25 miles in width, which, too, penetrated inland as far as Niort, has constantly contracted its dimensions since the above-named date, and is now nothing more than a small bay, known under the name of the Creek of Aiguillon. The constant deposit of marine alluvium would scarcely be a sufficient cause for this rapid increase of the land; it is, therefore, probable that at this spot the upper layers of the ground are regularly in a course of upheaval. Farther to the south, La Rochelle, which owes its name to the position which it once occupied on a rock almost isolated in the midst of the water, now only communicates with the sea by a narrow channel, often choked up with mud. Brouage, another fort which, in the Middle Ages, was a town of important trade, is now nothing more than a ruin, some distance from the sea. The district of Marennes, to which the name of "Colloque des Iles" was once given, is now entirely connected with the mainland; and the arms of the sea which cross it have been converted into draining-channels, salt-marshes, and oyster-beds. In like manner, the peninsula of Arvert, situated between the mouth of the Seudre and that of the Gironde, ceased to be an archipelago during the course of the Middle Ages. At Rochefort it has, indeed, been calculated approximately how much the ground has risen, the slips for ship-building, dug out in the time of Louis XIV., having been gradually elevated more than a yard. "The bank is pushing up," say the inhabitants of the coast, who have long since observed the gradual upheaval of the ground.

CHAPTER LXXX.

COASTS OF ASIA MINOR.—ANCIENT OCEAN OF HYRCANIA.—COASTS OF PALESTINE AND EGYPT.—THE ADRIATIC GULF.

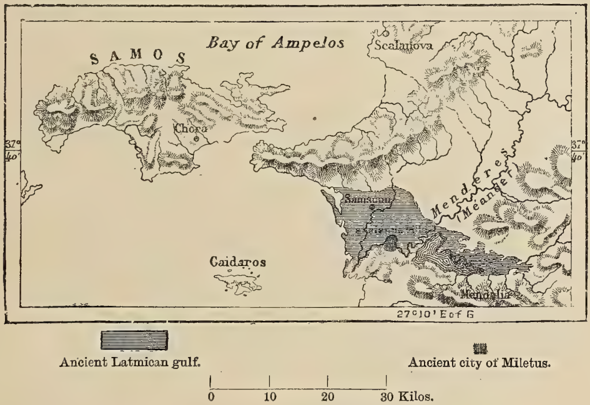
PHENOMENA of upheaval are also very common in the islands and round the edge of the eastern basin of the Mediterranean. Like Sicily and several parts of the coasts of Italy and Greece, a considerable number of islands—as Malta, Rhodes, and Cyprus—are surrounded with circular terraces more or less elevated above the level of the sea, and composed of calcareous or sandy rocks of recent formation. The northern portion of the Island of Crete has risen more than 60 feet during the present geological period. A study of the shores of Asia Minor proves that there also the ground has continued, since man inhabited that region, to rise with a rather rapid movement. During historic times this part of the continent has gained a considerable belt of land at the expense of the Ægean Sea. It is not the alluvium of the rivers, or the matter washed up by the sea, which has caused this increase of the land, for the Anatolian rivers are very inconsiderable, and the water which bathes the coast cannot, on account of its great depth, throw up much sand. It must, therefore, be in consequence of a slow upheaval of the earth's crust that the ruins of Troy, Smyrna, Ephesus, and Miletus have gradually become more distant from the coast, and appear to be receding still farther inland. From the same cause so many islands in the Ægean Sea which were once separate are now united, or are connected with the mainland, and form headlands or hills surrounded by low-lying plains. The testimony of ancient authors is unanimous as to these encroachments of the shores. Thus it is said that the two sections of Lesbos, Issa, and Antissa have become united, that the bays have been converted into inland lagoons, and that various islands have joined on to the mainland at Mindus, Miletus, the Parthenion Cape, at Ephesus, also at points near Halicarnassus and Magnesia. At the time of Herodotus, the mountain of Lade, not far from which the Ionian galleys fought a battle with the Persian fleet, was an island; at the present day it forms part of the mainland, and stands in the midst of the plain of the Meander. Since the date of Strabo and Pliny, several other islands have similarly become headlands. The former Latmican Gulf is converted into a lake, known under the name of Akiz. The encroachments of *terra firma* on this gulf have added to the eastern coast of Asia Minor about 67 square miles in less than two thousand years. This retirement of the sea took place likewise in preceding ages, for the town of Priene (Samsoun), which at the time of Strabo was 4½ miles from the shore, had been built at a previous date on the sea-coast. In like manner the village of Ayasoulouk, where the ruins of the ancient city of Ephesus

may still be seen, is at the present time two leagues from the coast, and the former estuary which was commanded by the town is now converted into a marshy plain. Would the little river Meander, the total length of which is not more than 341 miles, have been able, by nothing but its alluvial deposits, to fill up lakes and estuaries of so large an area, and to modify so considerably the outline of the shore? It is therefore important that the discharge of this river and its annual deposit of alluvium should be exactly measured, in order that we may arrive certainly at the real cause of these encroachments on the part of the Anatolian coast, where, according to the ancient saying of Pausanias, "all is unstable and changing." According to M. de Tchihatcheff, this portion of the coast of Asia Minor has gained, since historic times began, an extent of about 185 square miles, equal to the area of the Isle of Wight.

Similar phenomena are, however, likewise taking place on the southern coast of Asia Minor. Near Adalia, the Lake of Capria, which was very extensive at the time of Strabo, first ceased to communicate with the sea, and then gradually

Fig. 237.—Lower Meander Valley.

Scale 1 : 1.000.000.



emptied, being now nothing but a marshy hollow: the surface of the peninsula has thus been increased by an area of 154 squares miles. On the north of Asia Minor, a great number of signs prove that there also the water has retreated before the shores and rocks of the continent. During the present geological period the area of the Euxine has been diminished, and, according to the traditions of the Crimean Tartars, it is still diminishing. Banks of modern shells have been left by the sea at considerable heights on the hills of Thrace and Anatolia; round the Crimea, salt lakes, stagnant marshes, now exist far inland in the place of former gulfs. Certainly enough, the Black Sea, before the opening of the Bosphorus, received from its tributary rivers more water than the sun and wind could evaporate, and must necessarily have much exceeded the level to which it now reaches. But if the earth itself had remained stationary and had not slowly risen, the sea-water would not have left the marks of its presence at any point higher than the former Strait of Isnik, the site of which is now dotted over with lakes which once formed a part of the sea. It is, perhaps, in consequence of the upheaval of

the ground that this strait was closed, and the water of the Black Sea, gradually accumulating in its basin, was compelled to open by force a new outlet through the volcanic fissures which have now become the Bosphorus.

A geological examination of Southern Russia and the plains of Tartary will preclude us from entertaining any doubt as to the fact that the Caspian Sea, the Sea of Aral, and all those innumerable sheets of water which are scattered over the steppes, were separated from the Euxine and the Gulf of Obi by a gradual upheaval of the continent. The plains are still covered with salt and marine remains. The inland seas and the scattered lakes are still inhabited by seals, and their fauna altogether presents an essentially oceanic character. Herodotus, Strabo, Ptolemæus, and all the authors of antiquity attribute to the ancient Hyrcanian Ocean an extent far larger than that of the Caspian of our day; most of them, indeed, considered this inland sea as a prolongation of the Frozen Ocean. This latter opinion, no doubt erroneous as regards a date two thousand years ago, would certainly have been true of some anterior epoch. After Humboldt's profound investigations on Central Asia we shall not, at the present day, show too great temerity in assuming that, during some portion of the present period, a vast strait, like that which once ran along the southern base of the Atlas, extended from the Black Sea to the Gulf of Obi and the Frozen Ocean. The vast depression of the Caspian plains, which is below the level of the sea, and, according to Halley, was produced by the shock of some wandering comet, is, on the contrary, really owing to a slow elevation of the ground.

The observations of the level made on the coasts of the Mediterranean have enabled us to ascertain not only that the larger portion of this inland basin of the ancient world, and many of the regions bordering on it, have gradually risen, but that they have, in addition, pointed out the limits of the area of upheaval. They may be distinguished with some degree of precision on the coast of Syria and Palestine; it may be noticed that in this region the surface of the ground is corrugated like that of water, and forms a series of waves and depressions fluctuating in contrary directions. The shores of the Gulf of Iskanderun are regularly gaining in width by means of the elevation of the ground as well as of the matter thrown up by the sea; but at Beyrout a tower is shown which is sinking farther and farther into the water. More to the south, the former Isle of Tyre is now connected with the continent, and several parts of the peninsula bear traces of the sojourn of the sea during some recent epoch. Lastly, Kaisarieh, and some other towns in Palestine, are included in an area of subsidence, as is proved by the remains of fortifications which are now visible below the level of the Mediterranean.

On the east, all the Egyptian coasts were still rising at a comparatively very recent epoch; for the Bitter Lakes and the banks of the Nile exhibit former sea-beaches on which modern shells are found. The canal supplying Suez with sweet water from the Nile partly follows the old canal of the Ptolemies, which was still used in the eighth century. This watercourse required no locks, whereas the modern channel reaches the Red Sea level by a lock 11 feet high, which seems to represent the extent of upheaval effected since the time of the Hegira. But at the present day the ground is sinking continuously and imperceptibly. Ruined towns are situated in the midst of the marshy plain of Lake Menzaleh, which is covered by the sea during the greater part of the year. Farther on, a former branch of the Nile, with the banks which bordered it, is entirely hidden by the waters of the Mediterranean. The same phenomenon occurs on the other side of the Delta. In 1784 the sea made an irruption into the interior of the land, and formed the Lake

of Aboukir, in the midst of a plain on which important towns once stood. In like manner it may be inferred, from the ancient descriptions of Alexandria and its environs, that a considerable subsidence of the ground must have taken place there during the centuries of our era. Artificial caves and catacombs, dug out in the days of the Ptolemies, and incorrectly known as "Cleopatra's Baths," are now invaded by the waves. On the shores of the Red Sea, not far from Suez, some sepulchral caves hollowed out in the calcareous rock have likewise been inundated, owing to the subsidence of the ground. Perhaps this movement in the ground of Egypt is common to all that portion of the Mediterranean which may be called the Egyptian Sea; for in the Island of Crete the western point has constantly risen during the modern epoch, but the side nearest to Egypt is gradually sinking under the water. As Strabo himself expressly said, nature is seeking to destroy the Isthmus of Suez, which she once formed between the two continents. Man, in his operations of cutting through it, is only anticipating the geological labour of centuries to come.

Along the shores of the Adriatic Sea, to the north of Zara and Pesaro, geographers have noted other phenomena of depression which mark the northern limit of the great Mediterranean area of upheaval. In the middle of the sixteenth century, Angiolo Eremitano propounded the opinion that the isles of Venice were sinking at the rate of about a foot a century; and this hypothesis, which was based upon a comparison of the buildings and the pavement of the streets with the water, has since been fully confirmed. In the Isle of St. George, Roman constructions are now found below the level of the lagoons; in other places paved roads are covered by the water, and churches and bridges have sunk in comparison with the surface of the sea. In 1731 Eustache Manfredi noted the same subsidence of the soil under the edifices of Ravenna; but he, in error, attributed it to the gradual elevation of the level of the Adriatic. In addition, an entire town—Conca—once situated not far from Cattolica, at the mouth of the Crustummio, has been entirely submerged for some centuries; and, when the sea is calm, the remains of two of its towers may still be seen under the waves. Giacinto Collegno thinks that all these alterations of level are produced by the deposit of the alluvium brought down by the Po, and the other rivers descending from the Apennines and the Alps. This must certainly contribute in no small extent to the general depression of the Venetian coasts of the Adriatic Sea; but probably it is not the only cause, for the opposite coasts of Dalmatia and Istria are also sinking, in spite of the compact nature of their rocks. At Trieste, at Zara, and in the Isle of Poragnitza, various works of man—such as pavements, mosaics, and sepulchres—may be seen below the level of the sea. Moreover, as Lyell remarks, the artesian borings which have been made in the delta of the Po, to a great depth below the sea, have brought up nothing but river-alluvium, which unquestionably establishes the fact of a gradual depression of the ground. The earth which is penetrated by the boring-rod at the bottom of the artesian wells was once situate above the level of the sea.

CHAPTER LXXXI.

SUBSIDENCE OF THE SHORE OF THE CHANNEL, OF HOLLAND, OF SCHLESWIG, OF PRUSSIA.

WHETHER it be that the whole of Central Europe participates in the movement of depression to which the shores of the Adriatic are subject, or whether the latter be merely a local phenomenon, it is nevertheless the case that the southern coasts of the Channel and North Sea are also sinking, although very slowly. On the coast of Brittany and Normandy, numerous forests, which have been submerged, and buildings surrounded by the sea-water, prove that the ground has sunk during the present period. In 709 the Monastery of Mount St. Michael was built in the midst of a forest, ten leagues (?) from the sea; it now stands, like an island, in the midst of sandbanks. The inroads of the sea are still continuing, especially in the Bay of La Hogue and in the harbour of Carteret. It appears, however, that various undulations, like those on the coast of Syria, also exist on these coasts; for in several places banks of sand and modern shells have been discovered at heights from 40 to 50 feet above the level of the sea. At some remote epoch, but nevertheless contemporary with man, the valley of the Somme was also upheaved; but, for thousands of years, it has been slowly subsiding, as submarine forests are found along the coast; and the peat-bogs of Abbeville, the bottom of which is situated below the Bay of Somme, afford no other *débris* but the remains of animals and vegetables which lived on the earth or in fresh water. When these peat-mosses began to grow, the ground of the valley must have been higher than the surface of the neighbouring seas.

In Flanders and Holland the phenomena of subsidence have been, if not more considerable, at least more important in their results, on account of the very low level of these countries in comparison with the sea. A mere enumeration of the successive catastrophes brought about by this gradual depression constitutes a terrible history. The plains of Dordrecht have become a forest of reeds (Biesbosch). The Zuyderzee itself—once a marsh, next a lake, and then an arm of the sea—is still continuing to sink: at the present time there is, it is said, sufficient depth for ships of heavier burden than those which used to navigate it in former centuries. Like a raft gradually sinking under the waves, Holland would be slowly swallowed up in the abyss if it were not that the inhabitants, accepting the contest with the elements, have walled in their country by means of dikes, and laid it dry by immense operations of drainage, which will never cease to be a subject of astonishment. Several *savants*, at the head of whom stands the eminent geologist, M. Staring, are of opinion that the gradual depression of the land which is thus

embanked is caused only by the subsidence of the alluvial ground, the weight of the dikes, and the incessant passage of man and cattle. However great may be the importance of these combined causes, the phenomena of subsidence which have been noted for the last fifteen centuries are considerable enough to warrant us in accepting Elie de Beaumont's hypothesis as to the depression of the ground of Holland. If, at least, we may judge by the mean level both of the pavement of the towns and of the fields under cultivation, the movement of depression is most rapid at the mouths of the rivers—the Scheldt, the Meuse, and the Rhine. At Calais the streets are more than a yard above the high tide, whilst the cultivated ground descends to the limits of the tide. At Dunkirk the height of the streets is not more than 23 inches, and the fields are ploughed at a level of a yard below the sea. At Furnes and Ostend the streets are still lower, and the level of the *polders* is always sinking. Near the mouths of the Scheldt it is 11½ feet below the high

Fig. 238.—Coast of Friesland.

tide. Farther to the north the ground gradually rises; but the streets of Rotterdam and Amsterdam are lower than the level of the equinoctial tides.

All the adjacent coasts—those of the south of England, and of Cornwall and Yorkshire, as well as those of Hanover and Schleswig—likewise afford certain proofs of a considerable subsidence, by their submarine peat-mosses, their submerged forests, and their former coasts now become islands. On the western coasts of Schleswig the subsidence has been, on the average, 13 feet during the present period. In this locality, at the bottom of the port of Husum, there was discovered, in the midst of a submerged forest of birches, a tomb of the Age of Stone, necessarily dating from a period anterior to the subsidence of the ground on which it stood. On the eastern coasts of Schleswig and Holstein many phenomena of the same nature have been remarked, which can only be explained by a gradual subsidence of the shore. The remains of an old castle, situated at the mouth of the Schlei, are covered by the water. Farther on, the stumps of the trees of an ancient deer-forest of the Middle Ages may be seen under the water, about half a mile from the

shore. In the Straits of Fehmarn are found the remains of an ancient wall; and, lastly, near Travemunde, two blocks of stone, which stood on the beach at the end of the last century, are now surrounded by water. These are facts which will not permit us to attribute, solely and wholly, to the action of the waves the transformation of several peninsulas into islands, and lakes by the sea-shore into arms of the sea. According to John Paton, Denmark and Schleswig-Holstein have lost, since the year 1240, an area of about 1,225 square miles, or one-eighteenth of the whole surface of the territory.

Farther to the east, all round the southern basin of the Baltic, the inroads of the water have led several geologists to admit that these countries are slowly subsiding. Rugen is broken up into islets and peninsulas; Bornholm is surrounded by submarine forests, one of which, according to Forchhammer, is 26 feet below the line of the shore. Other submerged forests fringe the coasts of Pomerania and Eastern Prussia. The Islands of Wollin and Usedom, situated in front of the mouths of the Oder, have gradually been eaten away by the waves. The sandy bar which impedes the entrance to the port of Swinemunde used to form a peninsula of Usedom, indeed, during historical periods. Lastly, according to the evidence of Barth, the point of Samland has been overwhelmed by the water, as may be easily recognised by the fact that the church of St. Adalbert, which was built about the end of the fifteenth century, at a point $4\frac{1}{4}$ miles from the sea, is now found in a state of ruin only 100 paces from the beach.

These are all facts which cannot be questioned. Nevertheless, we are not yet warranted in considering them as positive proofs of subsidence, for Voigt, and several other scientific observers, class them among the simple phenomena of erosion and deposit. However this may be, there are very strong reasons for considering the Channel and the southern waters of the North Sea and the Baltic as a trench of depression, an elongated valley, 1,100 miles in extent, separating the area of upheaval of Northern Europe from that which is bounded at its northern extremity by the coasts of Poitou.

CHAPTER LXXXII.

UPHEAVAL OF THE COASTS OF CHILI AND PERU.—PROBABLE DEPRESSION OF THE COASTS OF LA PLATA AND BRAZIL.—COASTS OF NORTH AMERICA AND GREENLAND.

THE New World—that double continent, the architecture of which is distinguished by general features of such simple grandeur—likewise exhibits a remarkable regularity in the action of its slow oscillations. The latter are much more easy to study than the movements of the more indented and irregular peninsulas of Europe, and are also better known: since the epoch when the illustrious Darwin noted the fact that a great part of South America was constantly rising, *savants* and observers have only had to confirm the result of his investigations.

It is principally on the coasts of Chili that the traces of the general upheaval of the country are quite self-evident. Round every headland, at the outlets of

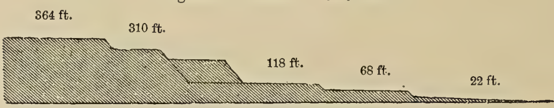
Fig. 239.—Coasts of Puerto San Jorge.

many of the valleys which cut deep into the mountainous masses on the coast, former sea-beaches may be distinguished, on which shells of the present epoch, like those of the creatures which are now living in the neighbouring bays, are scattered about or even heaped up in thick layers. These beaches, which are separated from one another by cliffs or escarpments of various heights, resemble the steps of a gigantic staircase. From these it may be readily seen that the coast was not raised by any uniform movement, and that intervals of comparative repose have elapsed between each of the stages furnished by the growing mass of rocks. On the hills of the Isle of Chiloe, Darwin found heaps of modern shells at a height of 347 feet. On the north of Conception, several lines of level cut out by the waves during the present period are found at an elevation of 600 to 1,000 feet. Near Valparaiso these levels are no less than 1,295 feet above the level of the sea; but north of this town they become lower. At Coquimbo they scarcely exceed 110 feet, and on the frontier of Bolivia they are only 65 to 80 feet above

the sea-level. Thus the rising action of the rocks is especially developed in those regions of the sea-coast which are in the same latitude as the loftiest summits of the Chilian Andes—Aconcagua, Maypu, and Tupungato. We may infer from this that these high peaks indicate the axis of the portion of the upheaved crust, and that the mountains themselves tend to increase more rapidly than the plateaux and shores situated below them. In fact, in Chili, as in Norway, the terraces which overlook former bays or the mouths of valleys are not horizontal, as they appear to be; they rise gradually towards the mountains, and increase in height as they recede from the present coast. The upheaving force acts, therefore, with more energy under the Chilian Andes than under the rocks of the adjacent coast. The white summits are gradually mounting up into the sky.

Trigonometrical measurements carried on for a long series of years will some day enable us to recognise this increase in the giants of Chili, and their upward progress into the regions of eternal snow; but, up to the present time, the only calculations which have been made on the subject of the rapidity of the upheaval of the Andes are based merely on the study of the sea-shores extended at their base. Comparing the present state of things with the evidence derived from history, Darwin proves that, during seventeen years, between 1817 and 1834, the ground at Valparaiso has risen 10 feet 7 inches, or about 7½ inches a year. This rather rapid movement was preceded by a state of comparative inaction, for, from

Fig. 240.—Coasts of Coquimbo.



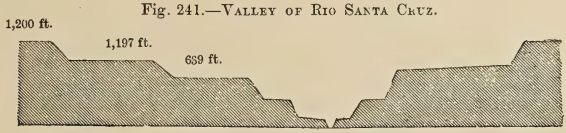
1614 to 1817, more than two centuries, the elevation of the shore, as proved by an examination of the localities, certainly could not have exceeded 5 feet 11 inches. At Coquimbo, Conception, and the Island of Chiloe, the emergement of the shore has taken place still more slowly. But, however imperceptible the phenomenon may be, it is none the less taking place during the course of ages, and must ultimately completely change the aspect of the American coasts. Several ancient ports which were once frequented are now inaccessible; other harbours have been formed, thanks to the fresh protecting points which have emerged. Numerous islands, always designated by the Indian name *huapi*, have become promontories.

The indications of a gradual upheaval are equally visible on the coasts of Bolivia and Peru. In the eastern zone of the Desert of Atacama the ground is covered at considerable heights with shells and saline efflorescence, and seems as if it had been abandoned by the ocean only the day before. Above Cobija, Iquique, and several other coast-towns, stages are marked out, similar to those at Coquimbo, and, like the latter, were once washed by the water of the Pacific. In front of Arica the sea has receded 165 yards in the space of forty years, and the merchants of the town have been, in consequence, compelled to lengthen their landing-stage. But in front of Callao, on one of the cliffs of the Island of San Lorenzo, a most interesting proof has been found of the elevation of the shore during the period it was inhabited by man. At a height of 85 feet above the sea Darwin discovered, in a bed of modern shells deposited on a terrace, roots of sea-weed, bones

of birds, ears of maize, plaited reeds, and some cotton thread almost entirely decomposed. These relics of human industry exactly resemble those which are found in the *huacas* or burial-places of the ancient Peruvians. There can be no doubt that the Island of San Lorenzo, and probably the whole of the adjacent coast, has risen at least 80 feet since the red man inhabited the country. It nevertheless appears that in our days the ground on which Callao stands has again sunk, for the place where the ancient town stood is now in great part under water. This depression is doubtless merely local, and only temporarily affects the general ascending movement of the coast; for, farther to the north, at Colon and at Santa Marta, and several other points of the coast of New Granada, the ground has visibly risen since Europeans first landed on the continent. By admitting, however, that Callao forms, in fact, the northern limit of the area of upheaval, it results that the mass raised presents from north to south a length of at least 2,480 miles. It is almost equal to the distance from London to Tobolsk.

On the coast of Brazil, especially at Bahia, various recent depressions seem to indicate that there also the surface of the continent is regularly sinking. The ascertained facts were not, however, sufficiently numerous to justify any categorical assertion, until Professor Agassiz, in company with some other geologists, undertook his famous exploration of the River of the Amazons. In the first place, he

Fig. 241.—Valley of Rio Santa Cruz.



verified the remarkable fact that, in spite of the enormous quantity of sediment drifted down by its current, this river does not form any deposits at its mouth. Instead of throwing out into the ocean a long peninsula of alluvium, like that of the Mississippi, or at least forming, beyond the regular coast-line, a delta similar to those of the Rhone, the Nile, or the Po, the Amazon, on the contrary, widens out in a large gulf towards the sea, and, in the great estuary, it is difficult to say exactly where the *mouth*, properly so called, commences. The banks of the river, and the islands which lie in its outlet, are not composed of alluvium brought down by the current of fresh water, but are all formed of rock with horizontal strata deposited by the water of the river at some former epoch, and long since solidified. Thus, in the contest which takes place in the estuary of the Amazon, as in every other river-mouth, between the currents of fresh and salt water, between the fluviatile alluvium and the erosions of the sea, the latter always prevail. Instead of encroaching on the ocean, the valley of the Amazons has been invaded by the latter for at least 300 miles; for the geological study of the ground on the two shores of the estuary proves that rocky layers, exactly similar to those farther up-stream, exist on the coast as far as the valleys of the Itapicuru and the Parnahyba. These two rivers once fell into the Amazon; but, in consequence of the erosion of their shores and those of the great current which they joined, the sea has advanced, as it were, to meet them, and they have thus by degrees become entirely independent of the Amazon system. In a similar way, the stream of the Tocantins is now only indirectly connected with the great central river, and, sooner or later, it must ultimately become isolated, as the

Itapicuru and the Parnahyba already are. The action of erosion, caused doubtless by a constant sinking of the ground, is still continuing. The shores are noticed to recede all round the estuary at Maranhao, at Piauhy, at Macapa, and on the coasts of Marajo. On the shores of the latter island, near Soure, a wide gulf, into which flows the Igarape Grande, has recently been formed across a forest for a space of more than 18 miles from bank to bank. The rocks in the vicinity, which once rose above the sea-level, are gradually becoming covered. At Bragança, the bay, which used to advance scarcely a mile and a half into the land, now penetrates for nearly five miles. The lighthouse of Vigia, which was built at some distance from the sea, was a very few years afterwards washed by the waves. A signal mast, which was set up in December, out of reach of the water, was surrounded by the sea in the June following. Facts of this kind render very probable the existence of a see-saw movement, which is upheaving all the western coast of America, from the Island of Chiloe to Callao, and depressing the eastern side of the Argentine Andes, of Patagonia, and Brazil. Thus a large portion of the South American continent is constantly gaining on one side that which it loses on the other, and is gradually making its way through the ocean in a westward direction. Agassiz assigns to this phenomenon of displacement a very ancient origin, for, in his view, the Antilles, which once formed the isthmus joining the two Americas, have been gradually submerged, and the rivers of Guiana, once tributaries of the Orinoco, have become independent rivers.

In North America the vertical oscillations of the ground have not been recognised over so considerable a length as in the southern continent; but the few observations which have been already made on some points of the coast, in California as well as round the Gulf of Mexico, render the hypothesis very probable that a general upheaval is taking place, to which one of the parallel chains of the Rocky Mountains, or of the Sierra Nevada, serves as axis. The shore-belt of Tamaulipas and Texas increases so rapidly in width, not only because the south wind—which here blows almost the whole year through—throws up a large quantity of sand, but also because the ground itself is rising. During eighteen years, from 1845 to 1863, the shores of the Bay of Matagorda have risen 11 to 22 inches. In consequence of this gradual increase in the land, which is also proved by the heaps of shells left far from the shore, it has been found necessary to transfer the port of Indianola to Powderhorn, a place 4½ miles nearer the entry. The peninsula of Florida is likewise being upheaved by some subterranean forces, as is proved by the coral-banks which are rising above the level of the sea. Those mysterious elevations, the "mud-lumps," which are scattered around the coast near the mouths of the Mississippi, the origin of which M. Thomassy has tried to explain, by attributing them to the pressure of subterranean water, also appear to testify in favour of a general upheaval of the region.

On the north-west coast proofs of upheaval have also been discovered in Alaska, where numerous old beaches are found strewn with driftwood, and where the Isanotski lagoon, still accessible in the last century, is now entirely separated from the sea. On the shores of British Columbia and Vancouver, English and American geologists have noticed similar phenomena. Near Los Angeles cliffs have even been raised to a higher level in recent times, and here the movement seems to be proceeding with a certain regularity at the rate of about three feet every century. Hahn also regards the deep cañons traversing Colorado as so many probable indications of upheaval.

The eastern side of North America is not rising uniformly, for although it is proved that the coasts of Labrador and Newfoundland are being slowly elevated, it is also proved that other regions are sinking. Lyell has ascertained that certain parts of the coasts of Georgia and South Carolina are subject to a movement of subsidence, and it is in consequence of a gradual depression, no less than from a constant action of erosion, that Sullivan and Morris Islands, at the entrance of Charlestown Roads, are incessantly diminishing in area. In like manner, all that portion of the coast which has as its centre the Bay of New York, and is bounded on the north by Cape Cod, and on the south by Cape Hatteras, has gradually sunk under the water of the Atlantic; and the subsidence has not yet ceased, at least as regards the coasts of New York and New Jersey. An isle which, on a map of 1649, is marked down as possessing an area of 290 acres, is at the present day not more than 100 square yards in extent at low tide, and at high tide is entirely submerged. If we are to put faith in tradition, the Straits of Hell-gate, which form the entry to the port of New York, are of recent origin. Two centuries ago the natives related to the Dutch colonists established in the Island of Manhattan, that, at the time of the fathers of their grandfathers, it was possible to cross dry-shod from one bank to the other, and that the sea only penetrated into the straits at the time of the great equinoxial floods. The land-surveyors employed on the survey have calculated that the shores of the Bay of Delaware lose, on the average, nearly eight feet every year. As far as it is possible to judge from the observations made since the colonization of the country, the slow subsidence of this portion of the American coast may be estimated at 23½ inches every century.

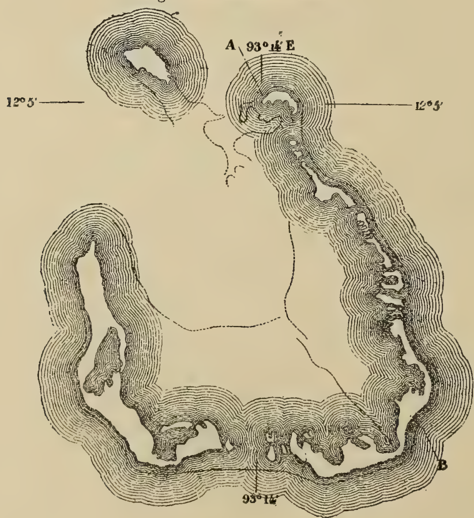
In the vast island of Greenland, which lies in the axis of North America, the progress of gradual subsidence, succeeding to a period of upheaval, appears to be much more rapid. For a long time the Esquimaux have been acquainted with this phenomenon, and the Danish colonists on the western coast have also been enabled to verify the facts since the last century, by noticing, for a length of more than 620 miles, rocks, advanced promontories, and, indeed, their own dwellings, gradually disappearing under the inroads of the water. According to Wallich, this receding movement is still going on as regards the bed of the sea to the south of Iceland, and the sunken land of Bass, marked out on all the old charts, has really existed. On the north of Greenland, from latitude 76°, and in Grennell's Land, as well as in the other polar regions of the New World, the directly contrary phenomenon is taking place. In his voyage undertaken to discover the open sea, Hayes noticed on all the coasts the existence of ancient sea-beaches, which had gradually risen to a height of 100 feet; added to this, all the cliffs of the headlands had been polished up to this height by the action of the ice. Kane also discovered about 32 feet above the present sea-level a fresh-water lake still inhabited by animals of marine origin. Payer noticed similar evidences on the east coast of Greenland and along the shores of the large island of Shannon. But no systematic comparative observations have yet been made in these Arctic regions for the purpose of ascertaining whether the period of upheaval still continues.

CHAPTER LXXXIII.

REEFS OF THE SOUTH SEA.—DARWIN'S THEORY AS TO UPHEAVALS AND DEPRESSIONS.

THE study of shores has not only enabled us to note the upheaval and subsidence of great continental masses; it has also made known to *savants* the oscillations of the tracts of ocean, for the numerous islands which lie either alone or in groups in the Indian Ocean have served as evidence to prove the movement of the ground on which they stand. Lines of erosion, parallel terraces, banks of modern shells, and all the other marks of the former presence of the water, point out, in each of the islands of the Pacific, as well as on the coasts of Europe and the

Fig. 242.—Keeling Atoll.

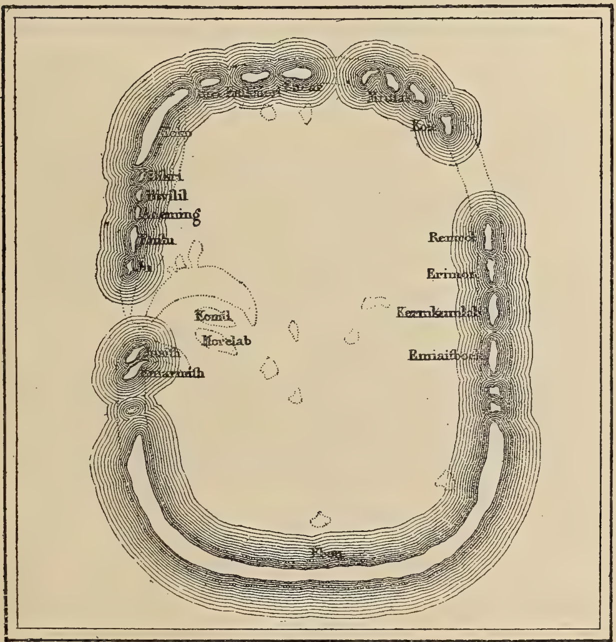


New World, the various upheavals which have taken place. But, in addition, most of these islands are surrounded with living girdles of corals, which exactly measure all the changes in level, either elevation or depression, to which the shores are

subject. The discovery of this fact, that the terrestrial oscillations are, so to speak, rendered visible by the work of polypes, is doubtless one of the most important achievements of modern geography; and it is to the patient investigations and sagacity of Darwin that science is indebted for it. By comparing his own observations with those of the explorers who preceded him, the English geologist has been enabled to point out, just as if he had witnessed them with his own eyes, the various movements which raise or depress the bed of the ocean, over an area as great as that of the two continents of Europe and Asia.

All travellers who have crossed the South Seas have been struck with astonishment at the sight of the reefs raised by the polypes in the midst of the water.

Fig. 243.—Atoll of Ebon.

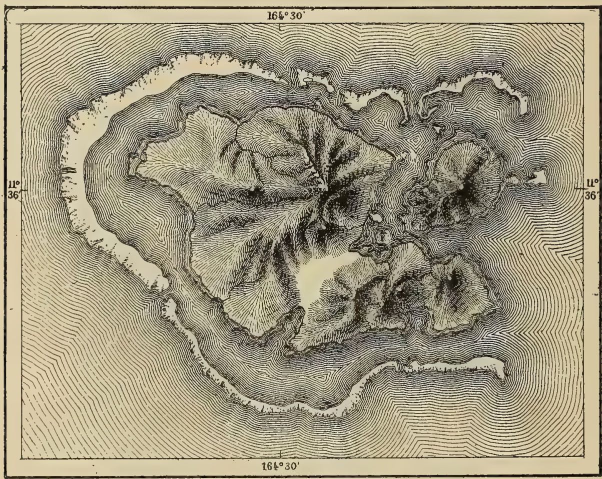


Some of these reefs circle round at a distance from islands, or even archipelagoes; they then form barriers of coral. Others, situated far from any land, are distributed in the shape of rings, or of more or less elongated crescents, round lagoons or bays remarkable for their pale green water; these are the *atolls*. In those parts of the ring where the construction of the polypes and madrepores have not yet reached the surface, the waves which flow over the submarine bar rise in foamy breakers; in other parts of the reef there are just visible above the waves rocks of a dazzling white or a delicate pink hue. Next comes a semicircular range of islets, like Druidical stones set up by giants in the open sea. Lastly, upon the emerged ground which occupies that portion of the *atoll* which is most exposed to the violence of the

waves and wind, cocoa-nut trees and other tropical growths wave in the air, either in mere groups or in regular groves. This is the most common form of the reefs among all the thousands of *atolls* which are dotted over the South Seas. When these coral-banks have not as yet reached the surface, their position is only pointed out by a circle of breakers; those that have attained the last stage of their development form a circular grove, which, seen from above, would look like a coronal of leaves floating on the blue water.

How have these wonderful reefs been raised? As was long ago proved by Chamisso, the French traveller, the polypes love to build in the midst of water which is breaking into foam; it may therefore be readily understood that wherever a submarine bank exists, the coral-reefs assume, like the breakers themselves, a more or less annular form. But in spots where the sounding-line reveals no shallows near the *atolls*, how have the polypes been able to raise from the bottom of the abyss their calcareous habitations? In order to explain this phenomenon,

Fig. 244.—Vanikoro, Island.



scientific men once hit upon a strange hypothesis; they looked upon every *atoll* as the circumference of a crater, which the submarine forces of the globe had raised up to a distance of a few yards from the surface, so as to form a base to the operations of the polypes. Although this explanation might be true enough for a very limited number of *atolls*, it would be incomprehensible how thousands and thousands of volcanoes should have been elevated to the same height below the level of the sea. Nor could it be understood why the craters of these supposed volcanoes should so often assume very elongated forms. Lastly, it would be impossible to conceive why, taking into account the multitudes of annular reefs of which several archipelagoes are composed, and especially the double range of the Maldives, 465 miles long by 50 miles broad, no *atoll* has ever distinguished itself by an eruption of lava or ashes.

The form of these reefs, therefore, has no connection with volcanic phenomena,

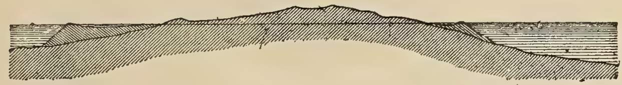
RELATIVE CHANGES OF LEVEL BET


O C E A N
GREENLAND
Sᵗ of Behring
NORTH AMERICA
Aleutian Iˢ
PACIFIC OCEAN
Labrador
Newfoundland
Azores
Missouri
Mississippi
Florida
Gulf of Mexico
Bahama Iˢ
Sandwich
Antilles
Mariannes
Marshall
Gilbert
Solomon
Iˢ Nouka-hiva
Iˢ Samoa
Low Archipelago
Society Iˢ
Iˢ Viti
Hébrides
Nˡˡᵉ Calédonie
Iˢ Tonga
SOUTH AMERICA
Amazon
Paraguay
Rᵒ de la Plata
ATLANTIC
New Zealand
O C E A N

properly so-called; and, like so many other facts in the terrestrial history, can only be explained by being attributed to slow movements of the surface. The subsidence of the bed of the sea will account for the formation of *atolls* and barriers of reefs; on the other hand, a gradual elevation of the ground explains the position of the corals which fringe the shore at a certain height above the waves. Thus, whether they rise or sink, the reefs formed by the polypes may serve as a measure of the vertical oscillations to which continental coasts, islands, and even the abysses of the sea are subject.

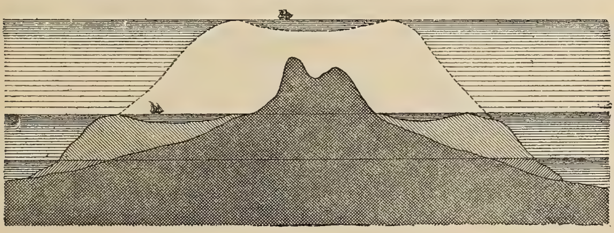
It is easy enough to verify the movement of land which is rising, as, in this case, we see the banks of coral resting upon the beach, and sprinkling with their *débris* that portion of the shore which is above the level of the sea. Often, too, the channels can be distinguished which once separated them from the coast, and on the high ground of several islands calcareous banks are found, which evidently

Fig. 245.—Section of Vanikoro.



owe their origin to polypes. With regard to the coral islands which are not included in the area of upheaval, they are surrounded by annular reefs, constructed in the midst of the water at some distance from the shore. When this distance is but small, and the coral banks are not very thick, there is nothing to prove that the level of the coast has changed; for the observations of *savants* prove that polypes

Fig. 246.—Growth of Coral on a Mountain slowly subsiding.

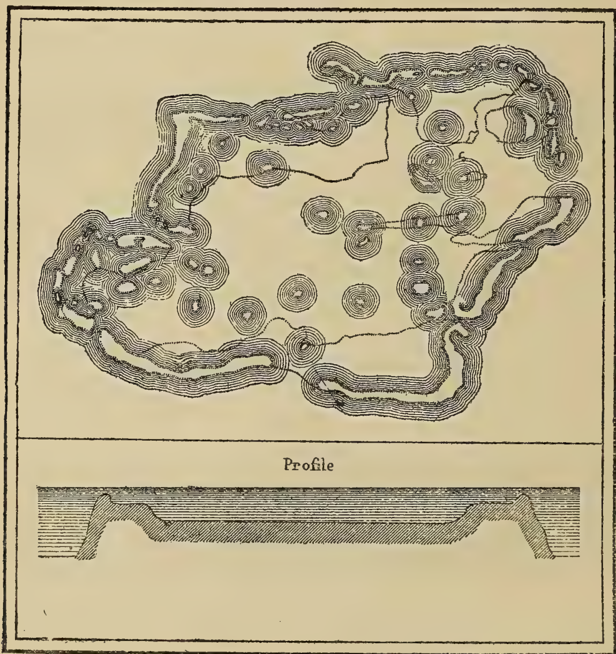


can live and build their rocky habitations at a depth of from 100 to 150 feet. Generally, however, the walls of coral and calcareous sand, which form the outer sides of the reef, descend much lower. Most of them lie on slopes composed of their own *débris*, and are immersed in the sea at a slope of 45° to depths of several hundreds and even thousands of feet. It is evident that in a case like this the bed of the ocean must have subsided. The polypes commenced their work of construction a few yards below the surface, and then, in proportion as the ground sank on which their coral edifice stood, they continued to build upwards and upwards, in order to approach the light. The mountainous islands, which they surround with their reefs, gradually diminish in height, leaving between themselves and the barrier of coral a channel of increasing width and depth. The time is approaching when, first having been reduced to the state of islets, they will become divided into isolated peaks, which one after the other will be submerged, and disappear in the

sea. Then all that remains will be an *atoll*, enclosing within its increasing walls a lagoon, in which calcareous *débris* is slowly gathered; narrow beaches and reefs, like the pieces of wreck still floating above a foundering ship, surround the spot where the island has been swallowed up. The natives of the *atolls* of Ebon relate that they have heard their fathers say that an elevated island, the hills of which were shaded by cocoa-nut trees and bread-fruit trees, once occupied the greater part of the lagoon. The isles disappeared, but the reefs are still maintained just above the level of the water.

When the subsidence of a whole archipelago of submarine peaks takes place slowly and regularly, it may often happen that the sea, striking forcibly against

Fig. 247.—Great Bank of Chagos.



the outer walls of the reefs, breaks this barrier, and hollows out for itself a free passage across the central lagoon. Then the banks of coral rise in the midst of the breakers on both sides of the newly-formed channel, and the original *atoll* is thus divided into two annular isles. In proportion as the submarine mass sinks, other ruptures of the same kind take place in each of the isolated fractions of the *atoll*, and the archipelago of reefs is ultimately composed of a considerable number of islets, which, in their turn, are also broken up. In this way are formed these wonderful groups of annular banks arranged in immense ovals.

The Atoll Ari of the Maldives is an example of this astonishing formation of coral islands. If we could represent in a drawing the shapes that the *ensemble* of

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the groups has successively assumed during the course of centuries, we should obtain a series of curves similar to those which geographers avail themselves of to delineate the slopes of a mountainous group. Sometimes, however, the movement of depression is so rapid, that the sea does not confine itself to opening channels here and there across the *atolls.* The coral insects do not build fast enough to maintain their dwellings on a level with the surface; they gradually perish, and the *atolls,* which layer by layer have been raised by innumerable generations of constructors, disappear, and form annular shoals. Of this kind is the great bank of Chagos, south of the Maldives, which the sounding-line shows to have once been one of the largest *atolls* in the Indian Ocean. In the Maldive group several verdant and recently inhabited islets are even said to have been slowly submerged. But there are no local traditions confirming these reports of the Arab navigators. The phenomenon is first mentioned by the geographer Albiruni, but in such vague terms that his exact meaning is scarcely intelligible.

CHAPTER LXXXIV.

THE GREAT AREAS OF UPHEAVAL AND DEPRESSION.—MOBILITY OF THE SO-CALLED RIGID CRUST OF THE EARTH.

OWING to the evidence which is furnished by coral reefs, which evidence, however, is supplemented at a large number of points by other indications, it is now possible to fix almost exactly the limits of the areas both of upheaval and subsidence, which divide between them the hemispheres included within the coasts of South America and Africa. Whilst the group of the Sandwich Islands is rising, as if it were still subject to the forces which are elevating the American continent, a gradual subsidence may be noticed in the archipelagoes of the central basins of the South Seas, the Bass and Society Islands, and also the Gilbert, Marshall, and Caroline Islands; in one word, all this "milky way" of islands, islets, and reefs, which extends diagonally across the Pacific for a length of more than 9,000 miles, and with an average width of 1,200 miles. These islands are the remnants of a former continent, which has sunk down with the people who inhabited it. Since the first European navigators visited these seas, several islands have disappeared, and others, such as Whit-Sunday Island, have considerably diminished in size.

In a parallel line with this great area of depression, which is at least twice as large as Europe, lies a wave of upheaval which coincides with the semicircle of volcanoes running round the western side of the basin of the South Sea. New Zealand, which is situated on the southern end of this rising, and is based on a long furrow of fire, is rising in certain places so considerably, that English colonists who have only arrived there a few years have been able to notice that the headlands increase in height, and that banks of rocks are gradually obstructing the entrance of the ports. At the commencement of the present geological epoch, the mountains of New Zealand were at least 1,900 feet lower than they now are, and the ice-floes from a continent situated to the east, floated with their load of erratic rocks on to the incipient islets, and were there stranded. But since that time the New Zealand Alps have risen ten successive times, as is proved by the ten terraces lying in stages on the sides of the mountains. Even at the present day the latter are still increasing. In ten years the shores at Lyttleton have risen three feet. The New Hebrides, the Solomon Islands, the northern and western coasts of New Guinea, the numerous islands which compose the great Sunda Archipelago (which latter are proved by their altogether Asiatic fauna, as studied by Wallace, to have once formed a portion of the neighbouring continent), are all now rising, after

having quite recently subsided, and banks of coral emerging from the sea are incessantly being added to the shores.

At the angle of the Asiatic continent the wave of elevation divides in a fork, so as to run round the China Sea, which is bordered by the gradually-depressed coasts of Cochin-China and Tonquin. To the north the upheaved region is continued towards America by the Philippines, Formosa, Liu-Kiu Islands, and Japan; that is, all the islands from Borneo to Kamchatka, through which passes the fissure of eruption of the volcanoes of the Western Pacific. Quite recently Russian travellers have discovered, on the coast of the great island Saghalien, heaps of modern shells, lying not far from the shore, on beds of marine clay, and also former bays, which are now converted into lakes or salt marshes. In like manner, it has been proved that the regions of the Amur are gradually being upheaved; for, in

Fig. 248.—Bridge of Adam or Rama.

order to maintain its level, the river has constantly to hollow out its bed between the cliffs, and on the plateau by the river-side semicircular sheets of water may still be seen, which are evidently former windings of the Amur.

On the west of the Sunda Archipelago, Sumatra, fringed on its eastern coasts by peninsulas which once were islands, and, indeed, still bear the name (*pulo*), seems to be the starting-point of another movement of upheaval, which embraces all the coasts situated round the Bay of Bengal. The Nicobar and Andaman Archipelagoes are gradually rising. Ceylon is likewise rising; at least, part of it, as is proved by the banks of coral lying in gradations one above another on the hills, and also by the traditions of the natives. But it is probable that the extremity of the isle is undergoing a slight see-saw movement, for Adam's Bridge, the chain of shoals which joins Ceylon to the Coromandel coast, which, too, according to the legend, formerly served as a road to the triumphal army of Hanuman, the monkey, appears to have once been a perfect isthmus. Scarcely three centuries have elapsed since the peninsula of Rameseram, whither thousands of Hindus went every year in pilgrimage, has become detached from the mainland, and formed an islet, like the ruins of a fallen pier. Farther to the north there has been an upheaval. If we may put faith in the Brahmin legend, Varuna, the god of the sea, two thousand three hundred years ago, ordered the waves to abandon the low plain of Malayâla, which extends along the Malabar coast between Mangalore and Cape Comorin. With regard to the basin of the Lower Ganges, it appears to form a part of the area of upheaval of the Bay of Bengal, and, with all its southern part, to be

gradually rising; for the tributaries of the rivers which traverse this region—the Kosi, the Mahanada, and the Son—are constantly shifting their mouths farther up-stream. The last-named watercourse has retreated more than four miles during the last eighty years. According to Mr. Ferguson, at the confluence of the Ganges and Gogra we find the western limit of the wave of upheaval, which commences at the islands of New Zealand, 8,000 miles away towards the south-east.

Almost the whole of the space occupied by Australia and the Indian Ocean, properly so called, is situated, like the central basin of the Pacific, in an area of gradual depression. Whilst from New Guinea to Sumatra and the Philippines a new continent is emerging from the water, the old Australian continent, so remarkable for its fauna and its flora, which seem to belong to some former geological period, is gradually sinking down, together with the surrounding isles—the Louisiade Archipelago, New Caledonia, and the reefs of the Coral Sea. Up to the present time, one portion alone of Australia is known to be experiencing a continuous movement of elevation—the district of Hobson's Bay, near Melbourne, which, according to M. Becker, is rising at the rate of about four inches a year. Be this as it may, the great mass of the continent is imperceptibly sinking, and the polypes which surround the coast are compelled to heighten their reefs more and more. The Indian Ocean, to the west of Australia, is almost entirely devoid of islands; but all those that emerge from the depth of the sea over a space of more than 3,700 miles in width are *atolls*, which would be slowly submerged if the polypes were not incessantly building up the edges of the reefs. Among these islands are the celebrated Keeling *Atoll*, which Mr. Darwin has studied so profitably for science, and the Maldive Archipelago, that double chain of sub-marine mountains, every peak of which is crowned with a coral tiara raised above the water.

Thus the space which extends over two-thirds of the circle of the globe, from the eastern coast of America to the western shores of the Indian Ocean, presents two areas of upheaval and two areas of subsidence succeeding one another from east to west. Next to the American continent, which is slowly rising, we have the innumerable low-lying islands of Oceania, the greater part of which would have long ago disappeared if it were not that the labour of the polypes has maintained them on a level with the waves. Next, there is developed, in a vast semicircle, pointed out from afar by its volcanoes, a large zone of isles and sea-coasts which are gradually rising, as if to replace in the future the whole continent of Australia. Lastly, the same causes which are depressing the bed of the Central Pacific are likewise lowering that of the Indian Ocean, with its shallows and its reefs.

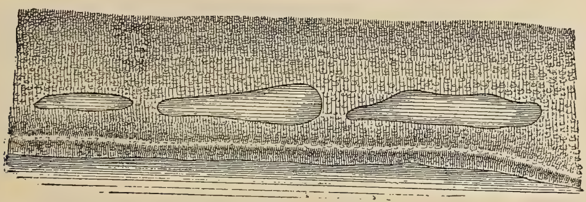
Beyond lies the enormous mass of Africa, the coasts of which have not yet been explored by scientific men, except, perhaps, over some small extent. Nevertheless, sufficient observations have been made to warrant us in considering Eastern Africa and the islands adjoining it as a third wave of upheaval, corresponding with those of America and the Sunda Islands. The banks of coral which surround Mauritius Island, Reunion, and Madagascar, and those which border the African coast from Mozambique to Mombaze, bear witness to the elevation of the ground. In like manner, the southern coasts of the Red Sea still exhibit at various elevations evident traces of the recent presence of sea-water. Most of the travellers who have visited these places, Ferret and Gallinier, Rüppel, Salt, Vâlencia, and Niebuhr, have been struck by the sight of reefs emerged from the sea, former sea-beaches white with salt, and bays which are now left far inland, and are converted into marshes. Quite recently M. Lejean has recognised the fact that, by the upheaval

of the ground, the former port of Jeddah is completely separated from the sea, and has become a mere lake; this port, at the time of Niebuhr, was still accessible to ships of small tonnage. The inhabitants of the coast assert that both the bed and the shores of the Red Sea change every twenty years.

Not far from the Isthmus of Suez on the north, the slow elevation of the ground is replaced by a contrary movement; but on the western side it is not yet known where the first signs are to be found of any rising of the ground. The observations of M. Eugène Robert on the coast of Senegal would, perhaps, show that this portion of Africa is in an area of upheaval. It is, however, a fact that beyond the African continent, Madeira, St. Helena, and probably the Canary Islands, the remains of the ancient Atlantis, are gradually sinking into the ocean. All these facts tell in favour of the hypothesis according to which the equatorial position of the circumference of the globe presents three waves of upheaval, separated from one another by three intervening depressions. The centre of each depression lies in the middle of an ocean; the three upheaved regions are the great Sunda Archipelago, a kind of continent in process of formation, and the enormous masses of Africa and America.

A comparison of continental and insular coasts subject to oscillation reveals the curious coincidence that the areas of depression are mostly indicated on the sea-

Fig. 249.—Shores of a Lake during period of Growth.

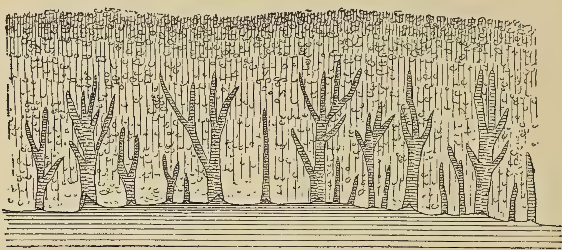


board by long narrow strips, separated from the mainland by marine inlets, while the upheaved sections are deeply indented, without any projections or peninsular zones beyond the coast-line. Hence the inference that a beach will probably belong to a rising or sinking area according to the form or direction of the shore. An explanation of this phenomenon is afforded by the study of lakes exposed to yearly floods, by which their outlines are changed from season to season. During high water the waves, striking against the projecting headlands and sandbanks, dispose in regular lines the sand, gravel, herbage, branches, and all other objects obstructing the current. Thus is developed along the beach a slightly curved embankment. But when the lake subsides the retreating waters sweep away all this refuse, and when the fall is rapid, the scour will even excavate channels at right angles with the coast, similar to those of the Caspian Sea.

These regular oscillations take place in obedience to some general law still unknown, although none the less certain. We cannot consider them, with Berzelius, to be mere accidents, produced by the subsidence or the rupture of the terrestrial crust. Neither must they be confounded with volcanic tremblings, from which they are distinguished by their excessive slowness and general character. If earthquakes have their tides, as is said to be proved by their greater frequency at the full and new moon, we cannot doubt that the slow oscillations of the terrestrial

envelope also have their regular cycles. Only the reason of these secular tides still remains unknown. Must we seek for it in some alteration of the physical conditions of the globe, or in the revolutions of some astronomical period? Some day, when scientific men have observed all the lines of level from the north to the south pole, and all the *débris* which have been left by the sea, as it were so many precise measurements, on sea-coasts and mountain-sides, we shall be able to exactly specify the dimensions of each wave of upheaval, and also what the impulsive force is which actuates them. We shall then know whether the regions that are elevated are always equal in extent to those that subside, and whether the surface, like that of every vibrating body, presents certain "nodal lines," round which the agitated portions arrange themselves in rhythmical figures.

Fig. 250.—Shores of a Lake during period of Diminution.



"The time will come," says Darwin, "when geologists will consider the quiescence of the terrestrial crust through a long period to be as improbable as an absolute calm in the atmosphere during a whole season of the year."

In the universe everything is changing and everything is in motion, for motion itself is the first condition of vitality. The firm ground long thought to be immovable, is subject to incessant motion; the very mountains rise or sink; not only do the winds and ocean-currents circulate round the planet, but the continents themselves, with their summits and their valleys, are changing their places, and slowly travelling round the circle of the globe. In order to explain all these geological phenomena, it is no longer necessary to imagine alterations in the earth's axis, ruptures of the solid crust, or gigantic subterranean downfalls. This is not the mode in which Nature generally proceeds; she is more calm and more regular in her operations, and, chary of her might, brings about changes of the grandest character without even the knowledge of the beings that she nourishes. She upheaves mountains and dries up seas without disturbing the flight of the gnat. Some revolution which appears to us to have been produced by a mighty cataclysm, has perhaps taken thousands of years to accomplish. Time is the earth's attribute. Year after year she leisurely renews her charming drapery of foliage and flowers; just as, during the long lapse of ages, she reconstitutes her seas and her continents, and moves them slowly over her surface.

APPENDIX.

PROGRESS OF RECENT GEOGRAPHICAL EXPLORATION.

INTRODUCTORY REMARKS.

ALMOST since the very dawn of history the many and various problems connected with the constitution and configuration of the terrestrial globe have engaged the attention of civilised peoples. The shape and size of our planet, the relative distribution and extent of land and water, the absolute elevation of the hard crust above the liquid level, the height and trend of the great mountain ranges, the sources of the mysterious rivers whose lower courses formed the seats of mighty empires, were questions discussed successively by the priests of Egypt, by the daring Phœnician seafarers and the philosophers of Greece. Doubtless most of these fundamental questions have at last been satisfactorily solved, and since the acceptance of the Copernican system and the discovery of the New World, followed by the circumnavigation of the globe, the issues have been narrowed down to a more exhaustive survey of the oceanic and continental regions already explored, and to the discovery of certain tracts on land and water, that have hitherto defied the efforts of the boldest pioneers of geographical research.

But even in this comparatively restricted field, how much still remains to be accomplished! At the meeting of the British Association at Montreal in 1884, General Lefroy, president of the geographical section, was able truthfully to remark in his opening address that "man's acquaintance with the planet he inhabits, with the earth which he is to replenish and to subdue, has been a thing of growth so slow, and is yet so imperfect, that we may look to a far distant day for an approach to a full knowledge of the marvels it offers, and the provision it contains for his well-being."

Nevertheless geographical research has in recent times progressed at an accelerated rate, and more has been accomplished during the last half-century than during the lull of over two hundred years which followed the discovery and rapid settlement of the American continent. A great impulse was given to enterprise in this direction by the work accomplished in South Africa by Livingstone, the first to cross the continent from sea to sea, and still more by the splendid results of the

journeys made to the east equatorial regions, some thirty years ago, by Burton, Speke, and Grant. But even after the great lakes Tanganyika, Victoria Nyanza, and Albert Nyanza were revealed to an astonished world, it was felt that much remained to be done before Africa could forego the title of the "Dark Continent," applied to it as much for the many geographical mysteries it continued to conceal as on account of the complexion of its aboriginal inhabitants. Even now, after the two greatest of these mysteries, the source of the Nile and the course of the Congo, have been cleared up by the magnificent achievements of Henry M. Stanley, it is still true that Africa remains what it was described a few years ago by Mr. Markham, "a glorious field of generous rivalry among civilised Europeans."

The following summary of recent exploration will naturally be limited to the work done since Stanley sailed down the Lualaba and found it the Congo. This exploit, the greatest probably since Columbus crossed the Atlantic and Magellan circumnavigated the globe, is distinctly epoch-making, worthily closing the latest and one of the grandest chapters in the glorious record of geographical exploration. It will here be seen that the fresh chapter now in progress, if hitherto unmarked by any results of surpassing importance, is at least already distinguished by the great variety of the work accomplished in every quarter of the globe. It gives promise of still greater achievements in the near future, and brings within a "measurable distance" the time when we may begin to hope for a final solution of all the great geographical problems still shrouded in mystery.

CHAPTER I.

AFRICA.

I.—Journey of Dr. Matteucci and Lieutenant Massari across North Africa from the Red Sea to the Gulf of Guinea.

DURING the month of August, 1881, an important geographical expedition was brought to a successful issue, while tragic interest was added to the event by the death of its leader in England, after braving all the terrors of tropical Africa. The circumstances are here briefly recapitulated from the proceedings of the Geographical Society for September, 1881.

On March 5, 1880, Dr. Pellegrino Matteucci, already well and favourably known by his journeys in Abyssinia and the Upper Nile region, and Lieutenant Alfonso Maria Massari, an officer in the Italian navy of high scientific attainments, left Suakin on the Red Sea, in company with Prince Giovanni Battista Borghese, with the intention of carrying out a grand scheme of exploration across Africa at nearly its broadest part: that is, through Wadai and Lake Tsad to the Gulf of Guinea. After traversing the Nubian steppes to Khartum, they pushed on through El-Obeidh, capital of Kordofan, to El-Fasher, capital of Dar-Fur. Here Prince Borghese gave up the enterprise, returning through Egyptian Sudan to Italy, while Matteucci and Massari passed onwards, and after some delay caused by negotiations, reached Abeshr, capital of Wadai, in October of the same year. Their letters from that place to the Italian Geographical Society announced their intention

of returning to Europe through Bornu and across the Sahara to Tripoli. Arrangements were accordingly made for their reception at Benghazi and Tripoli; but nothing further was heard of them till the end of July, 1881, when a telegram reached Rome announcing their sudden arrival on the Atlantic coast.

The particulars of the route followed from Wadai to the Gulf of Guinea were forwarded in a letter written by Dr. Matteucci off the Canary Islands to a relative in Italy, and published in Bologna in August, 1881. From this document it appears that after leaving Abeshr the travellers spent some time at Lake Fittri, and then passed through northern Baghirmi round the south side of Lake Tsad to Kuka, capital of Bornu, occupying two months on the journey, which, but for the protection of the Sultan of Wadai, would never have been accomplished at all, owing to the intertribal wars along their line of march.

From Bornu they made their way through Central Sudan to Kano, a large town of about fifty thousand inhabitants, and capital of the former Haussa state of the same name, now absorbed in the Fulah kingdom of Sokoto. From that place they proceeded by Dr. Baikie's route through the Nupé territory to Zariya and Bida, and thence to Egga on the Niger, which was reached on June 8th. Here they enjoyed some of the comforts of European civilisation, being hospitably entertained by Mr. Mackintosh, agent of the United African Company, and conveyed in the company's launch to Akassa, at the mouth of the Niger, where they embarked for Liverpool in the steamer *Coanza*. They arrived in the Mersey on August 5th, proceeding thence to London, where Dr. Matteucci, already in failing health, died on August 8th, at the early age of twenty-nine.

Although this expedition has not added greatly to our knowledge of the geography of North Central Africa, the route lying mainly through regions already known from the explorations of Barth, Richardson, Baikie, Nachtigal, and others, it is nevertheless memorable in the history of African geographical research as the first and hitherto the only one that has crossed the northern section of the continent from the Red Sea to the Atlantic Ocean. The positions of several towns and other places were astronomically determined by Lieutenant Massari, who also collected a good deal of information regarding the physical features, climate, and products of the regions traversed by the expedition.

II.—Lieutenant Wissmann's Journey across South Central Africa.

When Stanley reached the mouth of the Congo in 1876, besides determining the course of that river, he completed the journey across the southern division of the continent, from the Indian to the Atlantic Ocean. But in this part of his achievement he had already been anticipated by Dr. Livingstone and Commander Cameron, and was followed six years later by Lieutenant Wissmann. But while all previous routes lay from east to west, Wissmann's on the contrary took the opposite direction, from Loanda on the Atlantic to Saadani on the Indian Ocean.

Deputed by the German African Association to explore the territory of the Muata Yanvo, between the Zambesi and Congo basins, Lieutenant Wissmann and Dr. Pogge left Hamburg in November, 1880, for Loanda, which place was reached in January of the following year. Thence they made their way through Malansh (Malanje) to Kikassa on the Kassai, which was reached on October 2nd. Crossing that river, they found themselves in the Tushilange country, where the powerful chief, Kingenge, undertook to escort them to Nyangwe on the Lualaba. But on the road they discovered that Mukenge, another Tushilange chief, was a still more

powerful potentate, to conciliate whom Wissmann continued with Kingenge, while Dr. Pogge turned to the left in the direction of Mukenge's town.

Crossing the Lulua on December 1st, 1881, the travellers arrived on the 17th at Lake Munkamba, which had been described as "a vast sea," but which turned out to be a small sheet of water scarcely three miles long. It stands at an altitude of 2,230 feet above sea-level, and appears to have no outlet to any other basin.

From this point the expedition advanced to the Lubi, which is a tributary of the Lubilash (Sankuru), one of the Congo affluents, and which forms the boundary between the Tushilange and Basonge territories. Thence they proceeded through vast virgin forests all the way to the Lubilash, which at latitude 5° 7′ south was found to be as wide as the Elbe.

Beyond the Lubilash they traversed the densely peopled Beneki, Kalebue, and Milebue territories as far as the Lomami, another Congo affluent, beyond which Cameron's track was crossed. On April 17th, 1882, the expedition reached Nyangwe, where the two explorers parted company, Dr. Pogge returning westwards, and Lieutenant Wissmann continuing the journey eastwards. On July 18th, Lake Tanganyika was crossed from Plymouth Rock, a station of the London Missionary Society, to the town of Ujiji. Thence Wissmann proceeded through the capital of the famous Mirambo to the German station of Gonda, and so on through Mpwapwa to Saadani on the Indian Ocean. Here he arrived on November 15th, 1882, having spent nearly two years on his journey from sea to sea.

III.—Wissmann's Exploration of the Kassai.

After crossing the continent, Lieutenant Wissmann returned to the scene of his former labours, and at the instance of the Congo Association made a most successful expedition down the Kassai, the great southern tributary of the Congo. This time he was accompanied by Dr. Wolf and Lieutenant Müller, the explorers again starting from Malanje, on the Cuanza, on July 17th, 1884, and passing through the Cuango basin eastwards to the Kassai along the route already taken by Buchner, Schütt, and Pogge.

The Kassai was crossed on October 18th, the party arriving early in November at Subuku, residence of the powerful chief Mukenge. Here was founded the station of Luluaburg, on the banks of the Lulua, some distance above its confluence with the Kassai, and on May 28th, 1885, the expedition began the descent of the Kassai in a steel boat, the *Paul Pogge*, and twenty canoes of all sizes. Near the mouth of the Lulua rapids were encountered, but beyond that point there was no further obstruction to navigation.

After receiving the Lulua, the Kassai assumes the proportions of a great river, dotted everywhere with islands, and in this district known to the natives by the name of Zairé. Both banks are lined with forests said to abound in caoutchouc, and well stocked with game. On June 6th the flotilla passed the mouth of a tributary on the right bank, which was supposed to be the Sankuru, or lower course of the Lubilash, discovered by Wissmann and Pogge in 1881. On Stanley's map the Sankuru unites with the Lomame to form the Lubiranzi, which is then made to fall into the Congo some distance below Stanley Falls. But the Sankuru really joins the Kassai through two branches 830 and 1,000 feet wide, and its course is reported by the natives to be entirely free of rapids or other obstructions.

On June 19th the expedition entered the territory of the friendly Badinga people, next day passing on the left bank the mouth of another river about 140

feet wide, supposed by Wissmann to be the Loangue, although this stream has hitherto been made to flow into the Congo. A few days later they reached the country of the hostile Bakutus, reputed cannibals, the Kassai here contracting much in breadth and increasing proportionately in depth. But in the Badima territory, some miles lower down, it again assumes a vast size, broadening out in some places over 10,000 yards, but very shallow, and strewn with islands and sandbanks.

A little farther on the main stream is joined on the left bank by the Cuango (Coango), and on the right by the Mfini, from Lake Leopold. Between these two affluents the Kassai assumes the aspect of a series of lagoons and marshes connected by a complicated network of channels lined with wide strips of thorny scrub.

Below the Mfini junction the Kassai, here known as the Kwa, was navigated all the way to the station of Kwamouth on the Congo, which place was reached on July 9th, 1885, after a journey of forty-three days from the station of Luluaburgh. In its lower course the river again contracts to a breadth of about 450 yards, with a great depth and rapid current.

This exploration of the Kassai is of great importance, as determining the true character of a vast hydrographic system, and ascertaining the true relations of the Cuango, Sankuru, Loangue, and Kassai to the Congo. The Kassai itself is, next to the Mobangi, the greatest affluent of the Congo, being probably identical with the Kassabi, which in 1854 Livingstone found to be a stream 330 feet wide as far south as latitude 11° 15′ south. It was also met in 1875 by Dr. Pogge, 90 miles farther down near Degunda, where it was already 12 feet deep, flowing thence nearly due north, and receiving on its left bank its first great tributaries, the Rúembé, Chibumbo, and Luachim.

IV.—De Brazza's Journey from the Ogoway to the Congo.

There was a time when the Ogoway, which reaches the Atlantic through several mouths some miles below the equator, was supposed to be one of the great rivers of Africa. But the repeated expeditions of the Italian explorer, Savorgnan de Brazza, at last revealed its true character, as a comparatively small coast-stream stretching a very short distance into the interior. Then the hypothesis was put forward that it might possibly be a branch of the Lower Congo, forming with it a vast delta between the equator and 6° south latitude. This theory also was upset by the same explorer, who in the year 1880 actually crossed from near the source of the Ogoway overland to the Congo near Stanley Pool.

After leaving his station at Franceville, on the Upper Ogoway, on July, 18th, 1880, the traveller discovered the source of the Passa, a headstream of that river, and soon after reached the Leketi, an affluent of the Alima, which already belongs to the Congo system, being in fact the Kunia of Stanley's map.

Leaving the plateau of the Achicuyos, which separates the Alima from the M'pama (Stanley's M'paka) he arrived at the plateau of the Abornas, which in its turn separates the M'pama from the Lefini, that is Stanley's Lawson. Descending the Lefini on a raft to within a day's journey of its confluence with the Congo, he struck across country, in two days reaching the Congo near a populous part of the Ubangi territory. Returning thence to the Lefini, he reached the plateau of the Makokos, afterwards exploring the whole route across this plateau to the river Kunia. The chief difficulties on the road from Franceville on the Ogoway to Stanley Pool were found to be the passage of the rivers Leketi,

M'pama, and Lefini. Thus was solved the twofold problem, the Ogoway being shown to be a stream of minor importance in the hydrographic system of the continent, while its basin was shown to be quite independent of that of the Congo.

V.—Joseph Thomson's Journey through Masai Land to Lake Victoria Nyanza.

Mr. Thomson's successful journey from the east coast through the Masai territory to the north-east corner of Lake Victoria will always rank amongst the most brilliant chapters in the history of African exploration. Commissioned by the Royal Geographical Society to ascertain whether a direct practicable route existed through Masai Land from the Indian Ocean to the great lake, the traveller reached Zanzibar in February, 1883, and soon after started from Mombasa for the interior, at the head of a caravan consisting of 140 men all told.

The first section of the route, from the coast to Mount Kilima-Njaro, traversed a district already well known from the journeys of Krapf, Rebmann, New, and others. But beyond that point it entered the unknown region, which lies between Kilima-Njaro and the great lake, the passage through which had hitherto been barred by the fierce and hostile Masai people. A first attempt to penetrate from the south side of the mountain having been foiled, the expedition passed round by the east and north to the extensive Ngiri plain, which was reached on August 13th. This district proved to be the dried-up bed of a great lake, which had doubtless supplied Kilima-Njaro with the water which seems everywhere to be a necessary condition of volcanic activity. It stands at a level of 3,550 feet, and still retains numerous indications of its former lacustrine character, being dotted over with ponds, swamps and marshy tracts fed by springs.

From Ngiri the route took a northerly course to Lake Naivasha, discovered on September 29th, and Lake Baringo, reached and explored in the month of November. Naivasha is described as a comparatively shallow freshwater lake, forming an irregular square 12 miles long by 9 broad, lying at an elevation of 6,000 feet, and receiving a few feeders from the north, but without any outlet. Baringo, hitherto known only by repute, was found to be much smaller than had been supposed, being only 18 miles long by 10 broad. A remarkable feature of this lake is the large amount of water it receives, even in the dry season, without rising in level to any extent, or finding an outlet. "To make the puzzle more complete, the water is quite sweet, and harbours enormous numbers of fish, with some crocodiles and hippopotami. It could almost seem as if there must be a subterranean outlet." (*Through Masai Land*, p. 534.)

Baringo, some forty miles above the equator, marked the northern limit of the expedition, which turned thence due west to the north-east corner of Lake Victoria Nyanza, reached on December 10th, 1883. This section of the route, which ran partly through the Kavirondo country, was skirted on the north by two lofty mountains, Chibcharagnani (12,000 feet), and Elgon or Ligonyi (14,000), the latter excavated along its southern slopes by numerous artificial caves of vast size, inhabited by whole communities with their flocks and herds.

VI.—H. H. Johnson's Visit to Kilima-Njaro.

Kilima-Njaro, apparently the culminating point of the African continent, lies on the frontier of Masai Land, about midway between the coast at Mombasa and

the south-eastern extremity of Lake Victoria Nyanza. Discovered by the German missionary, Rebmann, in 1848, and subsequently visited by Baron Von der Decken in 1861, the Rev. Charles New in 1871, and Mr. Joseph Thomson in 1883, its true character was little understood before the expedition of Mr. H. H. Johnson, who was recently commissioned by the British Association and the Royal Society to thoroughly explore this volcanic region. This commission was most successfully executed by the distinguished traveller, who spent six months on the slopes or in close proximity to the mountain during the summer and autumn of the year 1884.

From his station at Moshi, on the southern slope, a magnificent view is obtained of the double-crested volcano, "the whole central ridge and both the peaks being completely visible. The eye first rests irresistibly on the splendid snowy dome of Kibo, absolute in whiteness under the glare of the vertical sun, with a few faint purplish blots, like the crater shadows on the moon's face, coming out where the bare rock breaks through the snow, and then in the few hollows, gaps, or crevasses, tender cool shadows of pale blue break somewhat the dazzling effect of unsullied white.

"To the left of Kibo a rounded descent of the mountain mass stretches down, with some few jags and modulations, till it passes away into the far-off plain, and to the right of the snowy dome a ridge nearly horizontal reaches to the sister and minor peak, the jagged Kimawenzi, which has merely patches and streaks of snow resting amid its strange black peaks and pinnacles." (*The Kilima-Njaro Expedition*, p. 154.)

Mr. Johnson made two attempts to scale the African giant, the second time reaching an altitude of 16,315 feet, or within a little more than 2,000 feet of the summit of Kibo, which has an estimated elevation of 18,800 feet. Kimawenzi, the minor peak, is probably 2,000 feet lower, both constituting a vast volcanic mass, which is not known to have been the scene of any igneous activity throughout the historic period. It is clothed with vegetation up to an altitude of 15,000 feet; while large animals, such as antelopes and buffaloes, roam as high as 14,000 feet, penetrating in their wandering up to the very snow line.

VII.—Discovery of the Sources of the Niger by MM. Josue Zweifel and Marius Moustier.

This interesting event was thus announced to the Paris Geographical Society, by M. Henri Duveyrier, on November 19th, 1880:—

"Of the two main branches of the Niger, the Joliba and Binue, the former is incontestably the larger, and it is consequently possible to know the source of that river without knowing that of the Binue. Up to the time of MM. Zweifel and Moustier's expedition it was admitted that this was in 9° 25′ N. lat., 9° 45′ W. long., on a mountain named Loma, and this knowledge was due to Major A. G. Laing. Whilst he was in Sulimania in 1822, he took two compass bearings of Mount Loma from the upper part of Mount Konkodugoré, south of the town of Falaba, and of the sources of the river Seli or Rokelle. The apex of this very acute angle was on a sharp-pointed peak, very nearly 91½ miles distant from Falaba. Consequently, the details of his observation being known, the position assigned to Mount Loma, by Major Laing, could be regarded only as provisional, owing to its vague and uncertain character.

"But is the river which rises in this pretended Mount Loma really the first and most distant rivulet, which, swollen by successive affluents, becomes the Joliba?

"This doubt, to which no one had given expression, but which had occurred to the minds of several geographers, is at last cleared up for the first time. At $78\frac{1}{2}$ miles to the south-west of Laing's Mount Loma, and only 193 miles from Free Town, in the British colony of Sierra Leone, MM. Zweifel and Moustier saw the Tambi-Kundu, or mountain head of the river Tambi. This river, which is longer than the Faliko, takes the name of the Joliba after their junction. It rises in 8° 36′ N. lat., 10° 30′ W. long., in one of the summits of a mountain chain, which bears the name of Loma, like that just mentioned. It is possible that the mountain chain of Loma is continued to the north-east with some interruptions as far as Major Laing's Mount Loma; and it is equally possible, as often happens in other parts of the world, that the name of a chain is a substantive, simply meaning 'mountain,' 'summit,' or 'chain of mountains,' and that in this case it is applied pre-eminently to the chief orographic feature of a whole region.

"Meantime we must heartily congratulate MM. Zweifel and Moustier on their principal discovery, viz., the Tambi-Kundu, or the farthest known source of the Joliba. We do not hesitate to say that this discovery is a considerable fact in the history of geographical progress during the year, and perhaps it will always retain its importance."

VIII.—Lupton Bey on the Welle-Kuta Problem.

Mr. Frank Lupton, better known as Lupton Bey since his appointment to the governorship of the Bahr-el-Ghazal provinces in Egyptian Sudan, after the death of Gessi Bey (Romolo Gessi) in 1881, has been cut off from direct intercourse with Europe for the last three years. But a letter from him, dated Jur Ghattas, November 6th, 1883, received in England early in 1884, throws some light on the chief hydrographic problem still awaiting solution in the African continent.

Towards the southern frontier of the Bahr-el-Ghazal region the land rises to a considerable elevation, developing a distinct waterparting between the three great basins of the Nile, the Congo, and the Tsad. All the streams rising on the northern slope of this divide, Jur, Tonj, Rohl and many others, belong to the Nile basin, flowing mainly in a north-westerly course to the Bahr-el-Jebel and Bahr-el-Arab (Bahr-el-Homr). But what becomes of those rising on the southern slope, whether they drain south to the Congo, north-west to the Tsad, or due west across the continent to the Old Calabar river (for this view has also been advanced), is still uncertain.

Of these streams the most important are the Welle, first heard of by Petherick, and afterwards explored in its upper course by Schweinfurth; and the Kuta, mentioned by Dr. Junker, Lupton Bey and other more recent travellers. The Welle has been very confidently identified by many geographers with Stanley's Aruwimi, or with one or two other large tributaries of the Congo from the north, while the Kuta has been with equal confidence sent to join the Shari, the great southern feeder of Lake Tsad.

But Lupton Bey now steps in, and so far simplifies matters by positively declaring, on information almost at first hand, that the Welle and Kuta are one and the same river, consequently concluding that both or neither flow to the Congo or Tsad, as the case may be. He writes:—

"If the map to which I refer [Petermann's of 1877] is correct, and the Kuta is the Congo as marked, the Welle is also the Congo, for the Kuta is formed by the junction of the rivers Mbomo and Welle; they meet at a place called Mabela,

about thirteen hours' march east of Barusso station" [that is, 90 miles south by west of Foro].

On the whole, Lupton Bey inclines to the view that the Welle-Kuta flows, not to the Shari, but to the Congo. "It seems to me," he adds, "that Lake Tsad is too far away from Barusso, where the Kuta is from two to three miles broad, for such a river to flow to it. If I remember, the Shari at its mouth in Lake Tsad is only about half a mile broad, much smaller than the Kuta at Barusso. Between the Makua and the Nungo (which river, I think, joins the Kuta four days' march west of Barusso) there are several large rivers. The principal are the Rubi, which joins the Welle, the Terre, which joins the Rubi, and the Mombago, which runs into the Nungo. Is the Nungo the Lualaba, and the Welle the Aruwimi?"

If these data can be relied upon, we have here a vast hydrographic system confined within the comparatively narrow space which stretches from the above-described waterparting to the Congo. It seems impossible that this system, united in the Welle-Kuta main stream, can possibly constitute the upper course of the Shari, being already much more voluminous than the lower course of that river. Lupton Bey's conclusion therefore seems inevitable, that the Welle-Kuta flows to the Congo, unless we are prepared to adopt Mr. Edward Heawood's suggestion, that it flows due west to the hitherto unexplored Lake Liba, and through it to the Old Calabar River and Gulf of Guinea. The problem would doubtless have ere this been solved, but for the troubles attending the rebellion of the late Mahdi, and the consequent relapse of Egyptian Sudan into a state of chronic anarchy and barbarism.

IX.—Mr. Schuver's Work in the Berta Highlands and North-West Galla Land.

Mr. Schuver, whose career of usefulness has unfortunately been cut short by his murder in the Denka country, deserves mention in this record of African exploration as the only European traveller who has yet succeeded in penetrating from Senaar southwards into Galla Land. In December, 1881, he reached the territory of the independent Berta highlanders, which marks the extreme southern limits of the Khedival possessions in this direction. It forms the waterparting between the Yal and Ror, flowing west to the White Nile, and the Yabus affluent of the Blue Nile.

He followed the Yabus for a considerable distance down to the plains of the White Nile, and was thus able to determine the source of the Yal affluent of the Nile, as well as to solve the hydrographic problem arising from the circumstance that the Sobat and Yabus have their source in one and the same lake. He explains, in fact, that there are two Yabus rivers, the word Yabus, as is so often the case, being a generic term applied by the natives of this region to designate any running water. Thus we have a Yabus flowing to the Blue Nile, as the Arabs assert, and a Yabus flowing to the White Nile, as determined by Mr. Schuver.

The Yabus of the Blue Nile has its southernmost and chief source at the foot of the lofty Mount Wallel, in lat. 8° 50′ N., while that of the Yal affluent of the White Nile lies in the western valleys of the Shugru mountains, the eastern base of which is skirted by the Blue Nile Yabus. Within the territory of the Aman Negroes the Yal bears the name of Valasat; but after passing the Banghe defile in a series of cataracts, falling 2,000 feet in 12 miles, it enters the Berta country as the Yabus, the name by which the other perennial stream in the same region is also known.

Mr. Schuver followed the western Yabus down to its confluence with the Owé, the chief river of the valleys south of Gomashe. Beyond this point it passes into the Burus plains, where its lower course takes the name of Yal, falling into the White Nile in the Dinka country below the Sobat confluence.

Although the area of his explorations was confined to a comparatively narrow district, it will be seen that the work performed by this intrepid explorer has been of a highly useful character. He has helped materially to remove the confusion hitherto prevailing, regarding the intricate hydrographic system of the region lying between the White and Blue Niles, west and east, and stretching southwards in the direction of the Sobat basin.

X.—The Discoveries of MM. Capello and Ivens in South Africa.

These two travellers, already known in connection with an expedition to the regions east of Benguela and Angola, have for some time past been engaged in a much wider field, including a great part of the vast Zambesi basin and a portion of the Upper Congo lacustrine districts. The results of their discoveries and rectifications have not yet been published in any accessible form; but an official document has lately been issued by the Lisbon Geographical Society, containing a brief summary of the work accomplished by them during their recent expedition from Mossamedes south of Benguela to the Portuguese possessions on the east coast.

Amongst the most important achievements mentioned in this circular are the rectification of the course of the Cunene, wrongly called the "Nourse River" on some English maps; the determination of the Cuarrai and its connection with the Cubango; a study of the hydrographic relations of Handa and of Upper Ovampoland; investigation of the Cubango between 15° and 17° S. lat. and of its eastern affluents; explorations in the basin of the upper Zambesi about Libouta and of the upper and middle course of the Cabampo tributary; discovery of the Cambai, the eastern branch of the Upper Zambesi; investigation of the sources of the Lualaba and Luapula, as well as of the northern tributaries of the Zambesi, with the discovery that the Loangwa and the Cafue are one and the same river.

The discoveries of these explorers determine, either directly or indirectly, the true relations of the basins of the Congo and Zambesi at the points where they seem to be most entangled. The particulars that they have obtained regarding the Bangweolo lacustrine region also considerably modifies existing notions, and in some respects confirms former statements of Portuguese authorities. The great Lake Bangweolo itself is now stated to be merely a marshy zone connecting two smaller lakes, the Bangweolo proper on the north and the Bemba on the south. The last statement is all the more disquieting, that the true character of Lake Bangweolo must have been well known to Livingstone, who spent many years in the district, and at last ended his days at Ilala, on its southern shores. It will therefore be wise to suspend our judgment on these reports, pending a fuller and more authentic account of the work actually accomplished by the two Portuguese explorers. As regards Bangweolo, it may meantime be mentioned that it has also been recently visited by M. Giraud, who has navigated its surface in his steel canoe. This explorer found that its emissary, the Luapula, flows not from its north-west, but from its south-west corner, running for 150 miles south-west before trending northwards to the Lualaba.

XI.—Captain Chaddock's Navigation of the Limpopo River.

The Limpopo, or "crocodile," river, which sweeps round the west and north frontiers of Transvaal, entering the Indian Ocean in Portuguese territory above Delagoa Bay, appears to have been hitherto strangely neglected by explorers. Although its general course was long ago determined with tolerable accuracy, little had been done to ascertain the true character of the stream before the late expedition, carried out with considerable energy by Captain G. A. Chaddock, and an account of which was published in the "Mercantile Marine Service Association Reporter" for February, 1885.

The party sailed from Liverpool on September 25th, 1883, in the steamer *Maud*, and after a long delay in Natal, arrived on April 14th, 1884, off the mouth of the Limpopo, which is known to the natives by several other names, such as Inhampura, Inhampallala, Inguenia, Oori, and more commonly, Meti or Mete. Penetrating through the southern channel, Captain Chaddock succeeded in crossing the bar against a current running at the rate of about four knots an hour. The channel was found to be very narrow, but correspondingly deep, in some places no less than 24 to 26 feet.

The river is described as being generally narrow and deep, the surrounding country low and level, very thickly peopled, and as far as explored apparently well adapted for agriculture. But except at the mouth of the river, which for a distance of about twelve miles is thickly fringed with mango trees, the land is almost destitute of any material suitable for fuel. A few miles, however, from Manjoba's kraal, which was the highest point reached, the land becomes hilly and well wooded, and it was reported that this high ground continued far inland and was perfectly healthy.

Captain Chaddock feels satisfied that the Limpopo is quite navigable and, unlike most African rivers, free from rapids or any other obstruction, at least as far as the Transvaal frontier. On April 19th, 1884, the expedition left Manjoba's kraal on the return journey, reaching the coast on the 22nd. The *Maud* appears to be the first vessel of any sort that has hitherto entered and navigated the Limpopo river.

XII.—Explorations of F. C. Selous in the Mashuna Country.

This traveller's operations have been confined mainly to the region lying between the Zambesi and the Limpopo, where he has cleared up many geographical difficulties, and corrected previous notions regarding the chief waterpartings and river basins. In a letter to the Royal Geographical Society, a detailed account is given of his work in the Mashuna country during the course of a second journey made to that district in the year 1882.

After stating that he crossed from the Upper Hanyane (Manyame) river northwards to the Zambesi, near the mouth of the Umsengaisi, and thence westwards along the southern bank of the Zambesi to Zumbo, and so on back again to his original station on the Hanyane, he goes on to say :—

"According to all the recent maps I have seen, little or nothing appears to be known regarding the physical geography of this part of Africa. Supposing the position of Lo Magondi's town (Mr. Baines's farthest point north in the Mashuna country) is correctly placed on the map, and that the position of Zumbo is also correct, then all the intermediate places, rivers, &c., marked on my map cannot be very far wrong. I was much surprised to find the mouth of the Panyame placed

on all maps west of Zumbo, whereas it really runs into the Zambesi at least 15 miles as the crow flies to the east of that place, as I have marked it" [that is, on the sketch map accompanying his letter].

"You will see that the great mountain chain of Umvukwe forms a watershed; all the rivers running from its northern slope flowing into the Hanyane, as the Umquasi, Mutiki, &c.; or else into the Zambesi to the west of Kebrabasa, as the Umsengaisi. All the waters flowing from the southern slope of the Umvukwe must run into the river Mazo. As far as I could learn from the natives, the Umvukwe runs right down to the Zambesi at Kebrabasa.

"I have marked the rivers Umquasi, Mutiki, Mabare, Umpinge, and Dande, each running separately into the Hanyane. It is possible that some of them join before reaching the Hanyane, though I think not. The rugged mountains to the west of Umvukwe rise like a wall in an almost straight line running east and west from the Zambesi Valley. The first range must rise sheer 1,000 feet from the plain. The country between the mountains and the Zambesi is perfectly flat, or slightly undulating and covered with *mopani* forests, and very dry. From the Hanyane right down to the foot of the mountains water is most abundant, but below them the Umsengaisi and Panyame and all their tributaries become broad-bedded sand-rivers, with little or no water above the surface.

"Between the mouth of the Panyame and the Umsengaisi there is not a river or rivulet of any kind running into the Zambesi from the south. I have marked a river running into the Panyame near its confluence with the Zambesi, the Vo-ang-wa (O-o-ang-wa). It is a broad sand-river over 300 yards wide, with not much water above the surface. The whole of the country travelled through was more or less thickly peopled by Mashunas or allied tribes."

XIII.—Consul H. E. O'Neill's Discovery of Lakes Amaramba and Chiuta.

Ever since he was appointed British Consul in Mozambique, a few years ago, Mr. Henry E. O'Neill has been incessantly engaged in the work of exploration in south-east Africa. The field of his operations has chiefly been the region lying between Lake Nyassa and the coast, and stretching from the Lower Zambesi northwards to the Rufigi river. Perhaps his most fruitful excursion was the journey made in the year 1884 from Mozambique to Lake Shirwa, during which he elucidated the peculiarly intricate lacustrine system south of Lake Nyassa, and discovered the small lakes Amaramba and Chiúta, true sources of the Lujenda river.

In his description of this journey as communicated to the Royal Geographical Society, the explorer observes that before starting from the coast he had collected information regarding the supposed connection of Lake Shirwa (Kilwa) with the Lujenda, which it seemed desirable to verify. It was reported that Shirwa had really no connection at all with the Lujenda, which took its rise a little farther north, in the two smaller lakes Amaramba and Chiúta, of which nothing had been heard; and further, that between Chiúta, the southernmost of these basins, and Shirwa, there existed an elevated ridge, forming a complete waterparting between the two. The position of Shirwa itself was also stated to lie somewhat farther south than it had hitherto been represented on our maps. He adds:—

"I may perhaps as well say at once that a personal exploration of the district has resulted in my being able to confirm, in every particular, the informa-

tion I have quoted above, and to show that I was truthfully and accurately informed."

Thanks to this exploration, we now therefore know that Lake Shirwa extends no farther north than 15° south latitude; that it is apparently a landlocked basin standing at an elevation of 1,900 feet above sea-level, without outflow in any direction, consequently that it is in no way connected with the Lujenda river system.

The Lujenda has its farthest source in the Mtorandenga swamp, just north of the above-described waterparting, whence it trickles as the Namiguru river north-east to the Tambo swamp and east to Lake Chiúta, in lat. 14° 48′ S. From this point the trend is due north to Lake Amaramba, beyond which it assumes the aspect of a considerable stream from 90 to 120 feet broad, and here first takes the name of Lujenda. Its course thence north-eastwards to the coast at Cape Delgado was previously known.

Lake Amaramba is a permanent sheet of water about 9 miles long and 2 broad; but Chiúta appears to be little more than a flooded swamp whose waters recede and advance, presenting very different aspects in the wet and dry seasons. With regard to the drainage of Shirwa, the explorer observes: "I do not wish to say that Kilwa never connects with this system of drainage, although I was told on the spot that it had not done so within the memory of anyone living there at the present day. The difference in level is so slight, and the country between the Mikoko river and the Mtorandenga swamp so nearly upon the same plane, that I believe very unusually heavy rains and an extraordinary overflow would so inundate the banks of the Mikoko and the adjoining streams, the Nkande and Nambasi, as to cause a connection between the waters of Lake Kilwa (Shirwa) and the swamps that give rise to the lakes Chiúta and Amaramba."

XIV.—R. Baron's Researches among the Lava Fields of Central Madagascar.

Mr. R. Baron, of Antananarivo, communicates to *Nature* for March 4th, 1886, the subjoined account of his recent explorations of the little-known volcanic regions grouped round Lake Itasy, in Central Madagascar :—

"The volcanic cones of this region are situated in two localities especially: in Mandridrano, on the western side of Lake Itasy, and in the neighbourhood of Betafo in Vakin' Ankaratra; the former being from 50 to 60 miles west, and the latter from 70 to 80 miles south-west, of Antananarivo, the capital. Both localities are about 130 miles from the sea on the eastern side of the island, and 150 on the western side. It is hardly necessary to say that all these volcanoes are extinct, and that there are none in activity at the present time in any part of Madagascar. On the west side of Itasy the volcanic cones exist in great numbers, and these, therefore, shall be first described.

"The extinct volcanoes of this district of Mandridrano extend for a distance of about 20 miles north and south, and perhaps 3 or 4 east and west. They are, for the most part, scoria cones. The cones are thickly studded over the district, in some parts clustering together more thickly than in others. There is no single large volcano to which the others are subsidiary, or upon which they are parasitic. Occasionally there is a series of cones which have evidently been heaped up by the simultaneous ejection of scoriæ from different vents situated on the same line of fissure, but so that the cones have run one into the other, leaving a ridge, generally curvilinear, at the summit. None of these extinct volcanoes reach the height of

1,000 feet. Kasige, which is probably the highest, I found by aneroid to be 863 feet above the plain (5,893 feet above the sea). Andranonatoa is perhaps next in height to Kasige. Kasige is a remarkably perfect and fresh-looking volcano, whose sides slope at an angle of about 40°. On its top is an unbreached crater, which measures, from the highest point of its rim, 243 feet in depth. Continuous with Kasige, and adjoining its south side, though not so high, there is another volcano, Ambohimalala, and dozens of others are to be seen near by.

"A very large number of the cones have breached craters, whence lava has flowed in numerous streams and floods, covering the plains around. These streams and floods consist in every instance, I believe, of black basaltic lava; a sheet of this lava, the mingled streams of which have flowed from Ambohimalala and some other vents, has covered the plain at the foot of Kasige to such an extent as almost to surround the mountain. Similar sheets are to be seen in other parts of the district, but they are so much alike that a description of one will suffice for all. Amboditaimamo (or Ambohidratrimo?) is a small volcano to the north of Lake Itasy, and at the northern confines of the volcanic district. It possesses a breached crater turned towards the east; from this has issued a stream of lava which, following the direction of the lowest level of the ground, has swept through a small valley round the northern end of the mountain, and spread out at its west foot. This sheet of lava, which is horribly rough on the surface, occupies but a small area of some two or three square miles. It has been arrested in its flow in front by the side of the low hills. It is cut through in one part by a stream which, in some places, has worn a channel to the depth of 80 or 90 feet. Its surface, which is slightly cellular, is covered by some hundreds of mammiform hillocks, which must have been formed during the cooling of the liquid mass. The hillocks are mostly from 20 to 30 feet high, and apparently are heaped-up masses of lava, and not hollow blisters. The lava itself is black, heavy, and compact, being porphyritic, with somewhat large crystals of augite.

"Another feature worthy of mention in this volcanic district is the lakes and marshes which occupy many of the valleys. Itasy is the largest of the lakes, and Ifanja the largest of the marshes.

"Lake Itasy covers ground, roughly speaking, to the extent of about 25 square miles. It may not improbably occupy an area of depression due to volcanic action; but be this as it may, there is a cause at its outlet sufficient to account for its formation. Here, lying in the river-bed, may be seen numerous blocks of gneiss, many of them blackened with a covering of oxide of iron; and beneath this gneiss lava may be seen. Several volcanoes cluster round the outlet; but there is one—an inconsiderable hill—situated on the southern margin of the out-flowing river, just above the rapids. There distinctly enough may be seen a low and much-worn crater, with its breached side facing the outlet; and gneiss blocks may be traced from the bed of the river all up the hillside to the crater. There has apparently been first an ejection of volcanic matter, followed probably by an explosion tearing up and flinging out the gneiss through which the vent was bored; hence the gneiss blocks are superimposed upon the lava. Thus the water has been ponded back. The river has now cut its way several feet through the barrier thus thrown across its course; and by this continual erosion at its outlet, and the accumulation of sediment, and the growth of vegetation at its head, the lake is slowly, though surely, decreasing in extent year by year."

CHAPTER II

ASIA.

I.—Travels of the Indian Explorer, A—K, in Tibet.

At the head of Asiatic exploration in recent times stands unquestionably the great expedition to Tibet, carried out during the years 1878—1882 by the native Pandit of the Survey of India, known by the letters A—K. As explained by General J. T. Walker, in his account of this journey communicated to the Royal Geographical Society, in the reports of the Survey these men are simply called by certain initial letters, in conformity with the custom of suppressing their names while still vigorous and liable to be again employed in similar work.

In that paper General Walker informs us that in April, 1878, A—K left Darjeeling, in the Sub-Himalayas, proceeding through the Chumbi Valley and across the Sanpo river to Lassa, capital of Tibet, where he arrived in September. Here he was detained a whole year, being unable to move forward till the following autumn, when he started northwards in company with a small caravan of Mongolians and a few Tibetans. The route taken was that from Lassa to Chaidam (Tsaidam), which rises from a general level of 12,000 to 13,500 feet, and 15,750 at the Lani La pass, 60 miles from the capital. Beyond this pass they entered the highly elevated plateau of Jang-tang (Chang-tang), that is, the "northern plain," which occupies the greater portion of Tibet.

A march of 90 miles across this grassy steppe brought them to the famous monastery of Shiabden, which, though lying at an altitude of 15,000 feet above the sea, has a permanent population of about five hundred persons. Farther on the highest point of the route was reached, at a pass 16,400 feet high, in the Dangla range, which forms the waterparting between the upper basins of the Yang-tze-Kiang and the Mekong, the former flowing to China, the latter to Indo-China and Camboja.

After a five days' march at this tremendous elevation, the party reached the Angirtakshia range, forming the northern escarpment of the Chang-tang plain, and supposed to be an easterly continuation of the Kuen-lun range in Western Tibet. Beyond this range the route descended rapidly to a level of 9,000 feet in the Chaidam plain, a comparatively warm region, with woodlands and much cultivated land.

Crossing Chaidam, the Pandit arrived towards the end of 1879 at Hoiduthâra, whence he resumed his northern journey the following March, soon reaching Yembi in Saithang (9,000 feet), where he was again detained till January, 1881. Crossing the Altyn Tag range by a pass 14,000 feet high, and descending into the Chinese province of Khansu to a level of under 4,000 feet, he arrived in six days at Saitu, or Sachu, the Chinese Tung-Hwan-Hsien, in lat. 40° 20′ N., E. long. 90° 20′, the northernmost limit of the expedition.

Thus the whole of Eastern Tibet was traversed in the direction from south to north in rather less than three years, for the first time since the famous journey of the French missionaries MM. Huc and Gabet. The relief of the land, the trend of the great mountain ranges, the disposition of several hydrographic systems, and the general physical aspect of the whole region, were carefully determined, and a large number of important positions astronomically fixed.

On the return journey, which for most of the way lay considerably more to the east, a still more valuable service was rendered to geographical science by the practical settlement of the controversy connected with the relations of the Sanpo, Brahmaputra, and Irawady river systems. Notwithstanding the arguments of M. Reclus, Mr. Robert Gordon, and one or two other modern authorities, it had long been assumed that the Sanpo flowed not to the Irawady, but to the Brahmaputra. This view is now shown to be correct by our explorer, the last section of whose journey, from Darchendo, in 30° N. lat., 102° 10′ E. long., westwards to Chang-pu on the Sanpo, intersected the valleys of all the great rivers flowing from the Tibetan tableland to China and Further India. On this point General Walker observes:—

"On July 9th, 1882, the Pandit started northwards up the valley of the Rong Thod river towards the great range of the Southern Himalayas, which he crossed at Ata Gang La pass, about 15,000 feet high. He then once more came on the elevated plateau of Tibet, and in a quarter which is of great interest to geographers; for it is the region of the waterparting between the eastern and western systems of rivers, and it constitutes an impassable barrier to the oft-asserted flow of the great Sanpo river of Western Tibet into the Irawady. For some 40 miles of his route the waterparting between the Giama Nu Chu and the eastern basin of the Sanpo lay on his right hand at a short distance. He then crossed it and entered the western basins of the affluents of the Giama Nu Chu, and from thence onwards for 200 miles it lay on his left hand, when he again crossed it. Thus there can no longer be any doubt that the Sanpo river merges into the Brahmaputra, as has been constantly urged by Colonel Yule and many of our ablest geographers."

II.—Colonel Prejevalsky's Explorations in Central Asia.

Soon after the Indian Pandit, A—K, had been despatched to Tibet from the south, the famous Russian explorer, Colonel Prejevalsky, made his second unsuccessful attempt to penetrate through that region from the north. In the years 1879—80 he made his way across Mongolia through Barkul and Khami (Hami) to Sachu, the northernmost point reached by the Pandit. Thus was effected a junction between the surveys of these two explorers, giving for the first time a tolerably accurate idea of the relief of the Asiatic continent along the meridian of 94° E. longitude, and in some places for a considerable distance to the west and east of that meridional line.

On that occasion Prejevalsky succeeded in advancing much farther southwards in the direction of Lassa, the ultimate goal of all his expeditions. After exploring Lake Koko-Nor, in the Chaidam (Tsaidam) depression, he crossed the eastern extension of the Kuen-lun range to a point about the 32nd parallel, some 170 miles north of the Tibetan capital, mainly along the same route that had been followed by the Pandit advancing from the opposite or southern direction. But here his further progress was arrested, and he was fain to retrace his steps to Mongolia.

Since the close of the year 1883, this indefatigable explorer has been renewing his efforts to reach Lassa from the north, meanwhile doing much important geographical work on the border lands between the Tibetan plateau and the Gobi depression. Here one of his chief triumphs has been the discovery of the true source of the Hoang-ho, which was hitherto known only by report. Writing from Eastern Tsaidam on August 4th, 1884, he says:—

"At the beginning of May we reached the Burkhan-Buddha range, guarding on the side of Tsaidam the lofty North Tibet tableland. We were three days climb-

ing this barrier, the pass through which is 15,700 feet high. But the fall on the other side is much shorter, for there lies already the great Tibetan Plateau, itself 14,000 to 15,000 feet high. Upon this plateau lie the sources of the two great Chinese rivers, Hoang-ho and Yang-tze-Kiang. In spite of the attempts made by the Chinese before the Christian era, and again last century, to explore the sources of these rivers, they never succeeded; and, in fact, down to the latest times Northern Tibet has remained, and partly still remains, a region quite unknown to geographers.

"Crossing the Burkhan-Buddha, and continuing about 67 miles farther through the desert tableland, we at last reached the wished-for goal, the source of the Yellow River. It is formed at an altitude of 13,600 feet by two streamlets flowing from the south and west out of the mountains scattered about the plateau, and is fed by numerous springs of the wide marshy valley (40 miles by 13) known by the name of Odon-tala, which is the Chinese Sing-su-hai, or 'Starry Sea.'

"From the source of the Hoang-ho we pushed southwards towards the Di-chu, as the Yang-tze-Kiang, or Blue River, is called by the local Tangutans. The water-parting between the two great Chinese rivers was 14,500 feet high at the place where we crossed it. Farther south in the basin of the Blue River the character of the ground changes rapidly into an Alpine country, where the herbal flora becomes sufficiently rich and varied.

"After an arduous journey of 67 miles through the mountains, we reached the banks of the Blue River at an altitude of 12,700 feet. Hemmed in by the hills, the river here has a width of 300 to 350 feet, and is very muddy, with an extremely rapid and deep current. Finding it impossible to ford such a stream with our camels, and so continue our journey southwards, we spent a week in the neighbourhood, thence returning to explore the great lakes of the Upper Hoang-ho.

"These basins, by right of discovery, I have named Russia and Expedition Lakes. They lie at a height of 13,500 feet, surrounded by mountains; they are very picturesque, and each has a circumference of over 80 miles. Fish are abundant, but again there is no great variety of species. Of waterfowl only Indian geese are numerous. Once we came upon a vast flock in a little neighbouring lakelet, and three of us in an hour and a half killed eighty-five."

The last news received from Colonel Prejevalsky is communicated in a letter dated, Oasis of Kiria, 53 miles west of Khotan, August 10th, 1885, describing his important journey between Lake Lob-Nor and Khotan. He writes:—

"On April 14th, 1885, we reached the Cherchen oasis, on the Cherchen-Daria, 40 miles from its exit from the mountains. This settlement, which contains about six hundred houses, was founded only ninety years ago by emigrants from Khotan, Kiria, Aksu, and Kashgar. From Cherchen to Kiria lead two roads, one through heavy sands, the other along the borders of the Tibetan plateau. We chose the latter, though more difficult route; for by this way we could thoroughly explore unknown mountains. Specially difficult were the first two days' travel, when for 58 miles, from Cherchen to the foot of the Tibetan hills, we had no water.

"In this part the marginal range has no general name, and I called it 'Russian,' as I had already named the lake on the opposite side of Tibet, out of which flows the Yellow River.

"The Russian range extends from north-east to south-west, between the rivers of Cherchen and Kiria, for a distance of about 270 miles. Everywhere on the side of the Tarim lowlands it stands out as a lofty precipitous wall, occasionally rising above the snow-line. Particularly high is its south-western section, where snowy

peaks and ice-fields extend in an unbroken ridge, over which, near the Kiria river, towers a colossal cone-shaped peak, apparently from 22,000 to 23,000 feet above sea-level. This I named the 'Tsar Liberator.'

"From the snowy summits of these hills rivulets course down through deep gorges, beyond which they run out in the shifting sands of the desert. The mountains themselves, for a belt of 10,000 to 12,000 feet above the sea, are covered with tolerable pasturage, and are also rich in gold and jade, the *yu-shi* so highly prized in China.

"There are no easy passes across the Russian range into Tibet, though formerly there are said to have been roads along the Tolan-haji defile, near the tomb of Unchelik-pashim. After marching about 280 miles from Cherchen we reached the Nia oasis, on a rivulet of the same name, 30 miles from its exit from the Russian range. Two marches thence brought us to the Kiria oasis, the largest we had hitherto seen. It is distant 580 miles from Lake Lob-Nor, and the river Kiria, on which it is situated, flowing from the Tibetan plateau, runs for about 130 miles beyond the oasis, ultimately losing itself in the sands before reaching the Tarim basin."

III.—Mr. Carles among the Lava Fields of Korea.

Since the barriers of seclusion were broken down, and international treaties made with the Western Powers in 1882—3, the Korean peninsula has become an attractive field of geographical research.

The chief pioneer in this domain has been Mr. Carles, who has already made more than one important excursion into the interior. In April, 1885, he started from the west coast on an expedition, whose main object was to explore the Phyeung-Kang auriferous district, which lies 85 miles north-east of the capital, Seul, in the direction of Gensan. After crossing the granite hills which surround Seul, he unexpectedly found himself in a region of an essentially volcanic character. But although the mountains were all of igneous formation, among them were no cones to indicate the presence of volcanic action, the first signs of which were seen below Chheun-Mal, 37 miles from Seul, beyond a stream flowing to the Im-jin-gag affluent of the Han.

From this river a level plain extended a distance of 10 miles, apparently 3 or 4 miles broad, as far as So-rai-yol. After ascending 110 feet from Yong-dam, 68 miles from Seul, and passing between large blocks of lava strewn along the route, the explorer entered a vast plain stretching away to the north. The road skirted its margin, passing near the town of Chheul-weun, and then striking into the lava-field, "which in extent appears to exceed even that of the largest in Iceland."

Between Chheul-weun and Pai-namu-tjang (94 miles from Seul), a distance of 40 miles, there is only one break in the bed of lava. This break Mr. Carles attributes to the action of the stream flowing near Phyeung-Kang, basing his opinion on the appearance of the banks on either side, the uniform depth of the lava (100 to 140 feet), and the continuous and gradual ascent to the north.

The plain could be seen stretching 13 miles farther up to the divide of the eastern and western watersheds. About 30 miles north of this divide Mr. Carles had the previous year left a similar plain, stretching from An-byeum to Ko-san, but nearly 1,000 feet below the level of Pai-namu-tjang. "There are thus," he says, "three great oval fields of lava passing almost in a straight line through the mountain chain, which runs from the north to the south of Corea, at a height of about 1,500 feet above the sea near the divide, and of 500 feet on the lower levels.

There is also another plain about 4 miles wide and 12 miles long to the east of the Keum-Seung district, the direction of which is not so well defined, but in which the depth of lava is apparently even greater than that of the others."

In two places, near Chheul-weun and the town of Phyeung-Kang, there is a little trap-rock; but though there are many cone-shaped hills, no crater is visible in any direction to account for the enormous mass of lava. Possibly the explanation is, that at some remote geological epoch, when igneous energy was much more intense than it now is, the molten lava simply welled up through extensive fissures in the ground, and spread itself like a fiery lake in all directions over the surface.

IV.—Explorations of Major-General Sir C. M. Macgregor and Mr. Ernest A. Floyer in Western Balochistan.

After his visit to Khorasan in 1875, Sir C. Macgregor the following year made an excursion to Balochistan, traversing the whole country from the Persian frontier to India, and effecting some important rectifications of the orographic and hydrographic systems in the western districts. The results, as published in his "Wanderings in Balochistan" (London, 1882), may here be briefly resumed.

Beyond Panjgur the explorer entered the almost unknown region stretching along the Persian frontier northwards to Sistan, the exploration of which formed one of the main objects of the expedition. This tract, which had never been traversed since the days of Pottinger (1810), had continued to figure as the "Kharan desert" on our maps, on which its main drainage is made to flow northwards through the Mashkid (Mashkel) river to the Zirreh swamp, consequently to the Helmand basin. The point never having been determined by actual survey, the Mashkel was conjecturally traced by a line of dots as far north as 30° N. latitude.

But Sir C. Macgregor has at last cleared up the mystery by following this river throughout its whole course, from its head waters in Panjgur to its mouth in the Mashkel hamun, or depression. This swamp was found to lie under 63° E. long., 28° 20′ N. lat.—that is to say, fully 70 miles south of the Zirreh hamun, from which it was moreover proved to be separated by another depression, the Talab swamp, and by the Band-i-Naru range of hills.

The Mashkel, which is joined by the Mashkid, from Sarhad, above the romantic Tarik-Zorati gorge, is thus shown to have no possible connection with the Helmand basin, constituting, in fact, an independent area of inland drainage, like that of the Helmand itself, and of so many others in Asia and Africa.

It so happened that Sir C. Macgregor's explorations were carried out in the same year as those of Mr. E. A. Floyer, and that they continued eastwards that traveller's work, commencing a little to the east of his farthest eastern point, the two routes in no case overlapping.

Subjoined are some of Mr. Floyer's more important discoveries and rectifications, as described in his "Unexplored Balochistan" (London, 1882):—

1. The removal of the town of Anguran some 40 miles from the position assigned to it on Major St. John's map; 2. The discovery of the Shafiri, a considerable headstream of the Jagin, flowing from the Aphen-Band range; 3. The determination of this range itself, which was found to run east and west under 26° 30′ N. lat., at an elevation of 3,600 feet; 4. A survey of the Ab-washur waterparting between the Minab basin and Bashakard, thus exploding the theory that the Bampúr river reaches the coast through the Minab; 5. The exploration of the

Upper Haliri and its head waters draining from the Isfakana hills, and the southern slopes of the Jamal Bariz range.

Where Mr. Floyer crossed the Haliri, in 28° N. lat., 57° 40′ E. long., it was already 30 yards wide and 4½ feet deep, and was found to be flowing in a south-westerly direction to the fertile Shahri district. Here it would almost necessarily form a junction with the stream flowing south-west from Bampúr, whose farther course had hitherto been the subject of so much speculation.

Mr. Floyer rejects, apparently on good grounds, the Jagin and Rapsh (Bint) outlets, and argues with much force that the united Bampúr-Haliri is in fact the Upper Sadaich, which he had already ascertained to flow from the Shahri plains through the Shimsani pass southwards.

Although not yet completely cleared up, it seemed evident that we have here the true clue to the mystery, which can be absolutely removed only by traversing the hitherto unvisited districts of Rudbar and Shahri lying between Bampúr and the Ab-washur waterparting.

V.—French Explorations in Tongkin.

Amongst the purely geographic expeditions made by the French since their late occupation of Tongkin, the most important was probably that undertaken in 1881 by MM. d'Augis and Marcel Courtin, with the object of penetrating through the He-ho or "Black River"—that is, the great western affluent of the Song-Ka,—into the Chinese province of Yunnan. One of the chief inducements to occupy the country was the hope of being able to open up the southern provinces of China, and establish permanent trade relations with that region, through this very river Song-Ka and its main upper branches. But from the subjoined account of MM. d'Augis and Courtin's expedition, it will be seen that these expectations were doomed to disappointment, the main water highways of Tongkin not being navigable very far inland.

The expedition reached Wan-Giom, near the Chinese frontier, without meeting with any serious disaster. But at that place M. Courtin's death from the hardships endured in navigating the He-ho, compelled M. d'Augis to return. As far as the Phô-Bo rapid, the river is of easy navigation and gentle aspect; but above that point it flows with but slight interruptions between perpendicular granite walls, often frightfully overhanging, and looking as if a gigantic axe had cleft the primitive rock to hew out a passage some 900 feet deep. These walls are of equal height and identical geological formation, with large strata of carbonate of iron exactly reproduced on each side.

In the rainy season the river rises for nearly 23 feet, and the enormous pent-up body of water, when storm-driven, undermines the base of its granite prison to such an extent that huge masses of rock are precipitated into the bed of the river, forming enormous rapids, which alter the level and render the navigation perilous even for native canoes.

These rapids are constantly increasing: M. d'Augis counted fifty-four of them up to Wan-Giom, and found at Thac-Keu a complete bar in the shape of rocks some 23 feet high, a perfect chaos of débris rendering all farther canoe navigation impossible. Special mention is made of Thac-Be, Thac-Bomoi, and Thac-Tho-Ba as the worst obstacles, Thac-Bomoi being the most terrible of all, as he found to his cost, being twice wrecked on it, on the second occasion losing all his papers and

mineral specimens. Ill from fever and poisoned water, he succeeded, nevertheless, in descending the river to Hanoi, which he reached on December 24th, 1881.

He found various indications of mineral wealth in the volcanic rocks examined, such as iron, marble, malachite, copper, and in one place pockets of mercury. His observations also suggest the presence of a rich flora and fauna in north-western Tongkin. But as a highway of communication with the interior, the He-ho proved a total failure. (*Proc. R. Geo. Society.*)

CHAPTER III.

AMERICA.

I.—The Greely Arctic Expedition.

THE results of this singularly unfortunate, yet in some respects marvellously successful, expedition to the north polar regions have been published by its leader, Lieutenant Adolphus W. Greely, U.S. army, in "Three Years of Arctic Service: an Account of the Lady Franklin Bay Expedition of 1881—84, and the Attainment of the Farthest North" (London, 1886). When relieved at Cape Sabine by Commander Schley in June, 1884, the party of twenty-five originally constituting the expedition had been reduced to six souls in the last stage of destitution, all the rest having perished, mainly of famine and the hardships of all sorts endured while awaiting succour on one of the most exposed spots of the Arctic regions.

But during the two years passed in Grinnell Land much useful geographical work was accomplished, and many scientific observations carried out in the neighbourhood of the station. Here the most important result was the extension of the coast of Greenland far beyond the farthest point reached by Beaumont in the Nares expedition. While engaged on this geographical survey, Lieutenant Lockwood, one of the victims, and Sergeant Brainard, one of the survivors, reached the farthest point yet attained, that is, 83° 23′ 8″, or about four miles beyond the highest record of Captain Markham of the Nares expedition. One of the most pathetic incidents in the history of geographical discovery was certainly the interview between the rescuing party and Lieutenant Greely, already reduced to the last extremity, but still conscious enough to reply to their inquiries, "Dying like men, but beat the best record!"

As far as Lockwood reached, the coast of Greenland is broken up by fjords and fringed with islands, while the interior seemed to be completely ice-bound. There now remains only a comparatively small section of the North Greenland seaboard to lay down, in order to effect a junction with the farthest points east and west already determined.

So far back as 1877, Sir Joseph Hooker had expressed his belief that both Greenland and Grinnell Land are not so much ice-capped as ice-girt islands. This opinion has been fully borne out by the researches of the Greely explorers, one of whose most noteworthy achievements was the exploration of Grinnell Land itself. Hitherto nothing was known of this region except its coast and the tracts bordering on them in the neighbourhood of Discovery Harbour, Aldrich having carried the north coast as far west as 85° longitude Much of the whole outline has now been

filled up. Archer Fjord has been followed to its head; a large portion of the interior has been investigated; on the southern coast another inlet has been discovered and named Greely Fjord, and the coastline was seen stretching beyond to the north and south.

In the spring and summer of 1882, Greely himself made two considerable journeys into the interior, on both occasions making some notable discoveries, which add greatly to our knowledge of the physical geography of the Arctic regions. About the latitude of 82° N. is the large freshwater Lake Hazen, bounded on the north side by the lofty Garfield and United States ranges, on the west by the Conger Mountains. Encircling Lake Hazen are a series of smaller lakes and many streams, all of which send their waters into the central basin.

Even in April the river discharging into Chandler Fjord was found quite open along a part of its course, and the country generally remarkably free of snow. In summer the valleys are clothed with a comparatively luxuriant vegetation, which yields abundant food for large quantities of game. Besides grass in plenty, willows, beds of dryas and saxifrages were common; the scene was enlivened by the presence of butterflies, while bumble-bees and "devil's darning-needles" flitted about. Even on the south side of Archer Fjord, near Cape Baird, a fossil forest was discovered, one tree over a foot in diameter being found at an elevation of 800 feet above sea-level. That a great change of climate had taken place in the Arctic regions during comparatively recent geological epochs was already made evident by the discoveries made during the Nares expedition; and fresh proof was now afforded that there was a time when these high latitudes were comprised within the temperate zone.

Of Grinnell Land, Major Greely writes:—

"This fertile belt, 150 miles long and 40 wide, extends from Robeson and Kennedy Channels and Greely Fjord and the Western Polar Ocean. Its iceless condition depends entirely on its physical configuration. The abrupt, broken character of the country makes it impossible for the winter's scanty snow to cover it. Long, narrow, and numerous valleys not only offer the greatest amount of bare soil at favourable angles to the heating rays of the constant summer sun, but also serve as natural beds, with steep gradients, for the torrents from melting snows. The summer rivers drain rapidly the surface water, and long before continuous and sharply freezing weather comes, the land is generally free from snow, and the large rivers have dwindled to brooks. The deep intersecting fjords not only receive the discharging rivers, but, from their frozen surfaces furnish large quantities of saline efflorescence, which, mixing with the land snow, facilitates greatly its disappearance in the coming spring. Where such conditions do not prevail in Grinnell Land, ice-caps are found similar to the inclosed ice of Greenland traversed by Nordenskjöld."

II.—Captain William Glazier's Discovery of the True Source of the Mississippi.

For some time past the question of the true source of the Mississippi has been much discussed by American geographers. The difficulty attending its solution has been due partly to the unsettled state of the country about its headwaters, which is still occupied by Indian tribes. But in the month of June, 1881, Captain W. Glazier, of Milwaukee, organised an expedition for the express purpose of

exploring this district, and determining once for all the true source of the great river. "We proceeded," he writes to the Royal Geographical Society, "in canoes *viâ* Leech Lake to Lake Itasca, and accompanied by an old Indian guide, pushed forward to the south, and were rewarded by the discovery of another lake of considerable size, which proves to be, without the shadow of a doubt, the true source of the Mississippi, in lat. 47° 13′ 25″."

From notes taken during the ascent, it cannot be less than three feet above Lake Itasca, the hitherto supposed source of the river. The Mississippi may therefore be said to originate in an altitude of 1,578 feet above the Atlantic Ocean. Its length, taking former data as the basis, may be placed at 3,184 miles.

The origin of the river in the remote and unfrequented region of country between Leech Lake and Red River, not less than an entire degree of latitude south of Turtle Lake, which was for many years regarded as the source, throws both forks of the stream out of the usual route of the fur trade, and furnishes, perhaps, the best reason why its head has remained so long enveloped in obscurity.

The lake, which from its discoverer has been named Lake Glazier, was reached on July 22, 1881. It is fed by two streamlets flowing from a low ridge to the south, and named Excelsior and Eagle Creek, which form the remotest headstreams of the Mississippi. The Leech Lake mentioned in Captain Glazier's letter, lies about the same latitude, but considerably more to the east. It is the largest of all the lakes in this lacustrine district, and like them belongs to the Mississippi area of drainage, discharging its overflow through the Leech river to the right bank of the main stream soon after it emerges from Lake Winnibegoshish.

After the discovery, Captain Glazier started on a canoe voyage down the Mississippi, from its source to the sea. He reached the Gulf of Mexico on November 15th, 1881, having traversed the whole distance of 3,184 miles in 117 days.

III.—Mr. Bignell's Exploration of Lake Mistassini.

The mysterious Lake Mistassini (Mistasini) in Rupert's Land, Canada, was visited in the summer of the year 1884 by Mr. Bignell, who gave an account of his survey to the Quebec Geographical Society on January 30th, 1885.

The portion of the basin lying nearest to Quebec he describes as divided by a long narrow peninsula into two great arms, the most north-westerly of which, called Foam Bay, is about 300 miles from Lake St. John, and less than ten from the great waterparting of that portion of Canada which separates the rivers flowing into Hudson Bay from those draining through Lake St. John to the St. Lawrence, and forming the boundary between the province of Quebec and Rupert's Land.

One of the most remarkable features of this district is the small elevation of the watershed, which is nowhere more than six to eight feet in height, and sometimes much less, being found in some places most difficult to trace at all. The Hudson Bay Company's post, a small station in charge of the factor or trader, Mr. William Miller, was the only settlement of any kind found in the vicinity.

The climate is reported less severe than might be supposed from the latitude of the lake. In 1883 ice first appeared on its surface on November 4th, but the main body was not frozen over until the middle of January. In 1884 the ice broke up on May 22nd, and had not entirely disappeared until June 8th.

Mr. Bignell explored the lake for 120 miles without reaching the main body of water, and it is his opinion that this vast lacustrine basin is an expansion of the Rupert River, as the great American and Canadian lakes are of the St. Lawrence. As in the case of Lake Superior, the turbulence of its waves frequently gives warning twelve or fourteen hours in advance of approaching storms.

The actual extent and configuration of Lake Mistassini will not be accurately known before the publication of the report by the expedition recently organised to survey the district.

IV.—Everard im Thurn and H. J. Perkins' Ascent of Mount Roraima.

"Roraima the Marvellous," a huge mountain mass 30 square miles on top and 8,600 feet high, situated near the converging point of British Guiana, Venezuela, and Brazil, had long been an object of great interest to naturalists, owing to the apparent impossibility of reaching the summit. It was known to be an isolated mass, the upper portion of which rose some 1,500 or 2,000 feet sheer above the base.

It was this section that seemed to present an insuperable barrier, and had in fact defied all attempts, until it was at last successfully scaled by Mr. im Thurn and his fellow-traveller Mr. Perkins in December, 1884. On the 7th of that month they ascended half-way up the mountain and built four huts at a convenient spot for taking observations. From the foot of the incline up to about 5,000 feet above sea-level is a grassy undulating slope, broken only by occasional clumps of trees and broad bands of boulders. Farther up the perpendicular cliff rises to a height of 2,000 feet, presenting an unbroken rocky wall impossible to ascend, except at one point, where a ledge runs diagonally up the face of the cliff, at last gradually merging with the topmost tableland.

The ascent was made on December 18th, when the summit was reached after a four hours' march from the station. The scenery on the top, never before beheld by eye of man, is described by Mr. im Thurn as of the most marvellous character. "The first impression was one of inability mentally to grasp such surroundings; the next that one was entering on some strange country of nightmares, for which an appropriate and wildly fantastic landscape had been formed, some dreadful and stormy day, when, in their mid career, the broken and chaotic clouds had been stiffened in a single instant into stone. For all around were rocks and pinnacles of rocks of seemingly impossibly fantastic forms, standing in apparently impossibly fantastic ways—nay, placed one on or next to the other in positions seeming to defy every law of gravity: rocks in groups, rocks standing singly, rocks in terraces, rocks as columns, rocks as walls, and rocks as pyramids, rocks ridiculous at every point with countless apparent caricatures of umbrellas, tortoises, churches, cannons, and of innumerable other most incongruous and unexpected objects.

"And between the rocks were level spaces, never of great extent, of pure yellow sand, with streamlets and little waterfalls and pools and shallow lakelets of pure water; and in some places there were little marshes filled with low, scanty, and bristling vegetation. And here and there, alike on level space and jutting from some crevice in the rock, were small shrubs in form like miniature trees, but all apparently of one species. Not a tree was there; no animal life was visible, or it even seemed, so intensely quiet and undisturbed did the place look, ever had been there.

"Look where one would, on every side it was the same, and climb what high rock one liked, in every direction as far as the eye could see was this same wildly extraordinary scene.

"Only after some time was the perception felt that there was after all some trace of order in this apparent disorder. What this order is, is rather difficult to explain briefly. The top of the mountain seems to be not, as was supposed, quite flat, but to have the form of a basin, very shallow relatively to its extent, its edge being formed by the actual rugged edge of the cliff.

"The surface of this basin seems to be divided up in a manner which, if it were artificial, would be very irregular, but which, as the work of nature is singularly regular, into a vast number of much smaller yet still very shallow basins, these small depressions forming the amphitheatre-like level spaces of which I have already spoken, the separating walls between them being represented by the curiously terraced ridges of rock, which it appeared are really irregularly semi-lunar, or even in some cases ring-like, in arrangement.

"Moreover it is to be remarked that of these ridges each is by no means one height throughout its extent. Each of them, like a miniature mountain chain, rises at curiously regular intervals to form rugged pinnacles or pyramids, up the sides of which the rude step-like terracing, just as elsewhere along the ridge, generally runs, as though to offer a means of access to the traveller even up to the highest points.

"The basins or depressions hold a considerable quantity of water, some of this being visible in the many small streams and pools described, much more being stored in the super-saturated vegetation of the marshes. Even at the time of our visit, after so long a dry season, rock and hollow alike were almost full of water; so that but little was then flowing from them over the cliff-face to fall below. Yet each single not very heavy shower of rain sufficed to swell the water in them to such an extent that the cascades over the cliff at once became of considerable size."

Some of these cascades have a clear fall of 1,500 feet, and form one of the most striking features of this remarkable mountain. In the district are several other masses of somewhat similar character, but of smaller size. The largest is the neighbouring Kukenam, whose summit, being considerable lower, was quite visible from the top of Roraima.

V.—M. Frederic Montolieu's Explorations in the Upper Orinoco Basin.

During the year 1880 M. Montolieu spent some time amongst the headwaters of the Orinoco, paying particular attention to the Ynirida, a tributary of the Guaviare, of which very little was previously known. His object was not only to study the topography of this hydrographic system, but also to seek for a route for Brazilian traders in the rainy season from the Upper Guainia (Rio Negro of the Amazons) to the Ynirida, where they resort for the purchase of sarsaparilla.

The course of the Ynirida he divides into two distinct parts. From its confluence with the Guaviare to the Mariapiri rapid or cataract it has a current of from three to four miles an hour, and many terrible rapids (*raudales*) here interrupt the navigation.

From Mariapiri to Guacamayo, the last Indian village the explorer was able to visit, about 45 miles below the source, the Ynirida becomes a lake almost without current and rapids. Numerous lagoons surround it, and only two unimportant hills are here visible. The valley of the lower course, on the contrary, is enclosed

between several granitic mountain chains, of which the chief are those of Mariapiri, Kubalé, and Mavécuri.

In the rainy season many rapids disappear, but from November to February navigation is only possible between the rapids. The water of the river appears black, but in reality has only a slight ferruginous tinge. The cayman, which is so common in the muddy and yellowish waters of the Guaviare and Orinoco, is not met in the Ynirida; but enormous anacondas are found instead.

The Ynirida descends from its source almost parallel with the Guainia as far as Kubalé in the direction from west to east; it then trends to the north-east, forming an acute angle with the Atabapo, which runs from south to north. It falls into the Guaviare at a point 15 miles from San Fernando de Atabapo, in 4° 2′ N. lat. 68° 10′ W. long.

VI.—Mr. F. A. A. Simons' Explorations in the Goajira Peninsula.

Commissioned by the Columbian Government, Mr. Simons undertook a thorough survey of the Goajira district during the course of the year 1884. This hitherto unexplored peninsula projects for 120 miles from the mainland in a north-easterly direction between the Caribbean Sea and the extensive Gulf of Maracaybo. Instead of a large fertile plain diversified by one or two isolated hills, as was hitherto supposed, Mr. Simons found it to a large extent a hilly region. "There are in fact two Goajiras," he writes; "one, known as the Lower Goajira, is the broad level plain extending from the river Rancheria to a little beyond the Teta. The other, or Upper Goajira, is the hilly sterile region between the Teta and Punta Espada."

The Upper Goajira is simply a volcanic eruption, a conglomeration of low hills, conspicuous from the many cone-shaped forms and parallel ridges in which they have been thrown up. These parallel lines run chiefly north-west by south-east, and are separated by two large plains, thus forming three distinct groups of hills running from sea to sea. The first or most important of the three is the easterly or Macuira range, a bold mountain mass rising in front of Chimare about 12 miles from the seashore, and terminating at the most easterly point of the Goajira peninsula, where it forms the rocky Punta Espada headland. Due to its elevation and position, it serves as a species of cloud-trap, detaining the lower clouds that drive in from seawards, impelled by the easterly trade winds, that blow here with great force most part of the year.

The second or central range, called the Parashi Hills, is entirely separated from the Macuira Mountains by a plain some nine miles broad, which gradually rises from both seas to a height of 350 feet towards the centre. These hills rise at Bahia Honda almost from the margin of the bay, and stretch as a narrow belt right across the peninsula. Formed of ridges of low hills seldom exceeding 1,500 feet, covered with scanty wood and intersected by valleys overgrown with prickly pear, they present a desolate, forlorn appearance two-thirds of the year, but yielding abundant pasture during the rainy season.

Some 15 miles south of Ruma, the range culminates in the Guajarepa peak, which rises 2,200 feet above sea-level. Between the highest peaks and the sea is the extensive plain of Ataipa.

The third or Cojoro range is more extensive than either of the two first, and presents some peculiarities, being flanked on all sides by numerous isolated knife-like ridges, some running parallel to each other, with broad valleys between, while

others are complete segments of circles. Towards the Maracaybo shore are several large mountain masses, of which Yuripiche, the highest, is a wonderful mass of igneous rock 2,800 feet in height.

All these hills, like the Parashi range, are destitute of vegetation, many so steep that the bare rock and stone-slides put all idea of growth out of the question, and with their weird shapes, immense boulders and caves, form a fitting retreat to the Cocinas marauders.

With this range is connected the celebrated Teta Goajira, one of the most striking sights in the peninsula. This almost isolated rock, which rises 1,200 feet above sea-level and 900 feet above the surrounding plain, is composed chiefly of trachyte with large crystals of felspar, similar to those of the Drachenfels on the Rhine.

CHAPTER IV.

AUSTRALASIA.

I.—Mr. Charles Winnecke's Explorations in the Northern Territory of South Australia.

AFTER several preliminary excursions to various parts of the interior, Mr. Winnecke conducted a very successful expedition to the Northern Territory of South Australia during the latter half of the year 1883.

The scene of his explorations was the hitherto unknown region near the western Queensland boundary line, between 27°—23° S. lat., stretching from the Kallakoopat Creek, an affluent of the Macuba tributary of Lake Eyre, to the Marshall River where it is joined by the Hay River near the Tarlton range. Within this space, hitherto almost a blank on our maps, the traveller has discovered and named various lakes and mountains, besides the Hay River, an important affluent of the Marshall.

The prevailing features of the country are high red sand ridges, offering very great obstacles to travel, mostly running from north-west to south-east, sometimes covered with spinifex and low scrub, and separated by sandy valleys more or less overgrown with the like plants, wattle, acacia, &c. Two creeks, the Field, a tributary of Mulligan or Eyre's River, running across the boundary line, and the Hay, flowing almost parallel with it, but more to the west, follow the general direction of these valleys, the first trending south-east, the latter north-west. Like many other Australian streams, they widen out into flats, flooded or dry according to the season, often densely timbered with large gum and box-trees, and covered with good grass and herbage. The salt lakes discovered by the expedition also to a great extent follow the north-west and south-east direction of the sandy valleys.

After leaving the old trigonometrical station of Minna Hill, the explorers followed a north-westerly course to the corner post of the Queensland and South Australian boundaries in 138° E. long., 26° S. lat., through interminable sand ridges and past various intensely white salt lakes, mostly long and narrow, the largest named Lake Dobbie, and a smaller Lake Florence. Some of these were firm enough to allow the camels to walk across, and it was noticed that all of them had an extremely high and steep sand ridge, invariably abutting on their western

side, while the country near their eastern shore always consisted of low sandhills or flats.

From the boundary post a north-westerly route was followed on the Northern Territory side through a perfectly desert country to about 25° S. lat., when an abrupt turn eastwards was made over the line into Queensland. In this arid and uninhabitable region the camels had no water for a stretch of 278 miles, which they traversed in sixteen days.

Continuing eastwards from the boundary line, the Mulligan River was struck, and from this point the party worked north-west, parallel with the Field Creek, which apparently joins the Mulligan, and then north-east to Sandringham Station on the latter river. The route then ran westwards, recrossing the Mulligan and Field, and following up the latter to a water-hole, called Alanajeer, near its origin in the hills named the Adam Ranges, a little south of the 23rd parallel. The flood-marks of the Mulligan were observed for a space of 7 miles; it had no defined channel, but was a succession of wide flats subject to heavy inundations.

Continuing westwards by the Adam Ranges, two high points of which were respectively named Mounts Tietkens and Smith, a wide sandy creek, named the Hay River, was reached, and found to be an affluent of the Marshall.

Here the explorer struck northwards, with the object of connecting with his previous work, which he succeeded in doing, reaching the Tarlton range, containing Goyder's Pillars, in sight of Central Mount Hawker. This mountain is near the westward and northward termination of the Jervois range, and is exactly in the centre of all Australia, a spot which many explorers have vainly tried to discover, where in 1881 Mr. Winnecke appears to have undergone great suffering, walking 300 miles through desert and spinifex, bootless, and ill from scurvy and rheumatic fever.

Having named another elevation, north of the Marshall, Mount Cornish, the party travelled along the Hay River in a south-easterly direction, naming Mount Winnecke on its eastern bank, and making excursions into the country on both sides. They ultimately reached a native well called Yarracurracoo, from which point farther excursions were made to about 24° 34′ S. lat., on one occasion coming near the Queensland border not far from Eyre's farthest point in 1845.

Leaving the well on October 5th, the return journey was commenced in a north-easterly direction to the Field River, two elevations on its western side being respectively named Mounts Knuckey and Dobbie, and some farther explorations made in the Adam Ranges. (*Proc. R. Geographical Society*, October, 1884.)

II.—Mr. D. S. Carr-Boyd's Expedition to Western Australia.

A successful excursion was made to the northern districts of Western Australia in 1883 by Mr. Carr-Boyd, a surveyor under the Queensland Government, who unfortunately died suddenly of heart disease on his return, on November 25th of that year.

After travelling in a southerly direction by Gregory's Creek, the explorer struck the upper course of the Victoria river some 20 miles from Delemere Station. The Victoria, which flows into the Arafura Sea near the West Australian boundary line, was followed up for 35 miles to a tributary from the west. This river was also ascended for some distance, the route being continued overland to another stream, which proved to be one of the main branches of the Victoria.

Beyond this stream a south-westerly course was taken to Stirling Creek, which

was followed down to its confluence with the Negasi. The Negasi was then followed to a point near its junction with the Ord, the whole country from Delemere Station to this point, some 300 miles in extent, being described as excellent pastoral land, well watered with running streams, creeks, and springs, and suitable for all kinds of live stock.

Having made a depôt at the junction of the Ord and Negasi, the party proceeded to trace the course of the former river, which was found to be entirely different from that laid down on the maps. Rising in Western Australia, for the first 30 miles it runs in a north-westerly direction, afterwards trending more north-easterly, passing into the northern territory of South Australia over the 129° meridian (the boundary line), and then striking northwards close to the border, and re-entering Western Australian territory.

A good road is stated to exist from the Ord to the navigable waters of the Victoria, and also to Cambridge Gulf, where there is a good natural harbour. The opinion was formed that the first place established as a port would command the trade of the extensive pastoral lands of the Ord and its numerous tributaries.

III.—Mr. R. Watson's Journey across Queensland.

In the early part of the year 1881, Mr. Robert Watson, late engineer-in-chief of Victoria, was commissioned by the Queensland Government to survey a route for the projected trans-continental railway from Roma to Point Parker on the Gulf of Carpentaria.

The party left Roma on January 14th, in the direction of Charleville, the soil being found for 70 miles as rich as any in Australia, and presenting no obstacles to railway enterprise. But beyond the Mitchell Downs, it became less fertile, scrubby, and somewhat hilly. About 35 miles before reaching Charleville the party crossed the Angellalla range, the only mountains of any importance occurring along the whole route to the gulf.

Beyond Charleville the surveyor followed the Warrego and Nive rivers, proceeding through Ellangowan, Burenda, and Tambo to Blackall. Here the expedition was joined by Mr. Frederick Hann, who took the command, proceeding by way of Aramac to Mount Cornish, and so on to Nuttaburra and Winton.

From Winton they travelled over Ayrshire Downs, through which the Wokingham Creek runs, and after passing to Diamantina river, crossed the Great Dividing Range, which is in reality imperceptible, although it really forms the waterparting between the western and the gulf waters.

A north-westerly course was then taken through excellent country to the Cloncurry river, which was crossed near Fort Constantine. The same general direction was afterwards followed to the Leichhardt river. Having travelled down the left bank of this river for 12 miles, the expedition came to a large creek; and learning that there were many others nearly as large as the river itself running in from the western side, they recrossed the Leichhardt and followed the eastern bank to Floraville (Chandos), where they again crossed about 4 miles below the falls near the confluence of the Alexandra or Landsborough river.

The country generally through which the expedition passed, is reported as comparatively level from end to end, there being only one range worthy of notice, the already mentioned Angellalla Hills, 35 miles from Charleville. For nearly the whole distance the soil is very rich, and suitable either for pastoral or agricultural purposes.

IV.—Mr. D. F. Van Braam Morris's Explorations in New Guinea.

Mr. Morris, Dutch resident of Ternate, made two journeys to the north coast of New Guinea in the years 1883 and 1884, which resulted in a considerable addition to our knowledge of this part of the island.

On the first occasion proceeding in the steamer *Sing Tijn*, to the island of Jamma (Tastu), west of Walckenaer Bay, he coasted the mainland for 25 miles to the mouth of the Witriwaai, a large river not found on any map. Some 8 miles farther east he discovered another river, the Wiriwaai, with a strong current discolouring the water far out to sea. Mr. Morris accordingly considers this to be the principal outlet, and the Witriwaai a former mouth of the river, which is about 270 feet broad and 7 deep.

Some 60 miles farther east, the *Sing Tijn* cast anchor in Sadipi Bay, in 35 fathoms of water. This inlet is deep and well sheltered, its longer axis running north-west and south-east, the eastern point terminating in a steep headland with reddish cliffs. Here the precipitous coastline is formed by the spurs of the Cyclops Mountains, which lie at no great distance from the sea, and rise to an elevation of 3,000 feet, culminating in Mount Doffon.

Mr. Morris's second voyage was undertaken with the steamer *Havik*, with which the river Aiberan was for the first time navigated for some miles inland. The Aiberan, or Amberno, which is the only important stream between Kurudu Island and Point d'Urville, has its most northerly mouth in 1° 25′ S. lat., and 137° 53′ E. long., where the channel discovered in 1883 was now found to be 800 yards wide, with an extreme depth of 7 fathoms. It is very broad and straight, its muddy stream flowing between low marshy banks at the rate of about 3 miles an hour.

From the village of Pauwi, reached after six hours' steaming from the mouth of the river, high land was sighted about 20 miles off, and on entering the hills next day, the banks became steeper and the stream somewhat narrower, but still with an average depth of 6 fathoms. The current also became stronger, especially after passing the western side of an island, where the river suddenly shoaled to 2½ fathoms. The farthest point reached was the north end of this island, named Havik Island, where the steamer ran aground and was got off with some difficulty.

The natives call the river the Mamberan, that is, the "Great River;" but though easily navigable for over 60 miles, it does not appear to be such an important stream as had been supposed. It has only one mouth, though it probably parts with much water through the swamps along its banks.

Mr. Morris does not think that it would be possible even with a steam launch to ascend much higher than the point he reached and named Bivouac Point, 60 miles from the sea. The current here ran 4½ miles an hour, the water was muddy, greyish in colour, and the sand from the bottom stained the hand like wet coal. He concludes that there must be some considerable rapids or falls at no great distance above Bivouac Point. The numerous rolled and veined pebbles, all from a sandstone formation, also suggest a rocky barrier cut through by the river.

V.—Mr. J. H. Kerry-Nicholl's Explorations in the King Country, New Zealand.

The King Country, which occupies an area of about 10,000 square miles in the Northern Island of New Zealand, is one of the most remarkable volcanic regions

on the face of the globe, vying with the Yellowstone region itself of the United States in the extraordinary variety and strange aspect of its natural phenomena. But previous to Mr. Kerry-Nicholl's recent expedition the true character of the country was very little understood, being still to a large extent held by semi-independent Maori tribes, and consequently of difficult access to Europeans. This intrepid explorer, who penetrated into the district from Taranga, on the east coast, in the month of March, 1883, thus sums up the results of his survey :—

"Up to the time of my journey, the King Country had never been surveyed, and consequently many of its remarkable geographical and geological features had remained but imperfectly known, the existing maps of this part of the colony being mere outlines.

"Altogether we accomplished over 600 miles of travel ; found twenty-five rivers not previously shown on the maps, with two small lakes; examined the hydrography of Lake Taupo [the great central basin] in relation to the four distinct watersheds flowing into that lake ; traced the sources of four of the principal rivers of the colony, viz., the Whanganui, Warkato, Whangaehu, and Manganui-a-te-Ao ; ascended Tongariro (7,300 feet), and examined its active crater ; ascended Mount Ruapehu (9,000 feet), the highest peak of the North Island ; traced the principal mountain ranges forming the central division of the King Country ; ascended the Kaimanawa Mountains to an altitude of 4,000 feet, and found the geological formation to be indicative of auriferous and other metalliferous deposits ; fixed the altitude of one hundred different points throughout the journey, from sea-level to over 9,000 feet above that standard, by which data the configuration of a large portion of the island may be arrived at.

"During this journey I had an opportunity of examining the varied flora of this division of New Zealand, and I obtained some of the choicest specimens of Alpine plants, and obtained their native names from the Maoris. I secured specimens from the highest altitude attained by plant life in the North Island, in the *Gnaphalium bellidioides* and the *Ligusticum aromaticum*."

Altogether this expedition must be regarded as the most important undertaken in Australasia since McDouall Stuart's venturesome journey across the Australian mainland from south to north in 1860-62.

Conclusion.

It will be seen that by the work of exploration above described, the blank spaces on our maps have almost everywhere been considerably reduced. The unknown regions of the globe have been approached from every quarter, and the sphere of geographical knowledge extended in all directions. These results, due partly to private enterprise, partly to the increasing liberality of corporate bodies, such as the British Association and the various European geographical societies, warrant the hope that by the close of the nineteenth century nearly all the waste spaces on the earth's crust will have been at least roughly surveyed. What remains still to be done in this direction may here be briefly recapitulated :—

Africa : 1. The Upper Zambesi Valley, and generally the regions stretching from the Zambesi northwards to the Lokinga (Mushinga) Mountains and the headwaters of the Congo basin, and westwards to the Upper Cunene, Coanzo, and Cuango rivers.

2. The basin of the Middle Congo, including most of the land

enclosed by the great northern bend, and the regions extending thence eastwards to the great equatorial lakes, northwards to the Nile-Congo waterparting, to Baghirmi and Adamawa. This is by far the widest field still open to geographical research on the surface of the globe. It comprises an extent of at least a million square miles, lying mainly between 10° N. and 10° S. lat., and stretching in one direction from the headwaters of the White Nile, through the Nyam-Nyam country, right across the continent nearly to the Gulf of Guinea. Its exploration involves a solution of the Welle-Kuta problem and a better understanding of the hydrographic system about Lakes Alexandra, Albert, and Muta Nzige.

3. Most of Somali, Kaffa, and Galla Land, especially between Thomson's farthest north and Schuver's farthest south, a region mainly comprised between the equator and 10° N. lat., and stretching from the Indian Ocean westwards to the Upper Nile basin.

4. Much of the region comprised within the great northern bend of the Niger.

5. Much of the Sahara and Libyan desert.

ASIA: 1. Most of the great Tibetan tableland.

2. The border lands between South China and the conterminous territories of Tonkin and Siam (Lao, Shan, and Muang States).

3. Gilgit, Kafiristan, and other parts of the Hindu-kush, with its western extension across North Afghanistan to Herat.

4. Much of the interior of Arabia, especially the southern desert region west from Oman and north from Hadramaut.

5. The Korean Peninsula.

AMERICA: 1. Alaska and the Arctic seaboard and islands.

2. Greenland, Grinnell Land, and the Polar waters.

3. Much of the Middle and Upper Amazons basin and the interior of Brazil.

4. South Bolivia and Gran Chaco.

5. Parts of Patagonia, the Chilian Andes, and Tierra del Fuego.

AUSTRALASIA: 1. Various parts of Central and Western Australia.

2. Most of New Guinea.

3. Parts of Sumatra, Central Borneo, and Celebes.

4. Much of Melanesia, especially the interior of New Britain, New Ireland, and of the larger islands in the Solomon and New Hebrides archipelagoes.

NOTE.—During the present geological epoch the Antarctic lands and waters will probably remain for the most part beyond the scope of geographical exploration.

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